Materials
in Design Engineering

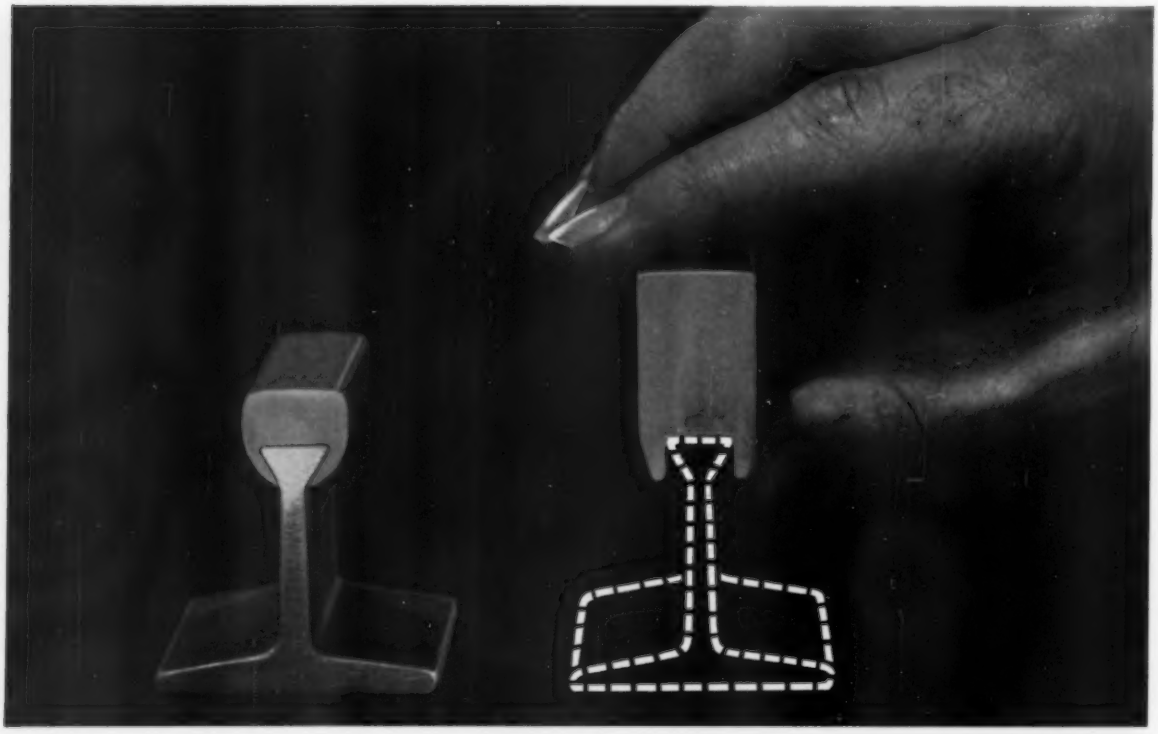
new directions in materials testing

page 117

Acetal Moldings vs Zinc Die Castings—Page 105 Functional Styling with Wire—Page 113 Complete Contents—Page 1

JUNE 1961

COPPER FOR CONDUCTIVITY TEAMS UP WITH STEEL FOR STRENGTH



...in a compact, low-maintenance conductor system for heavy-current industrial applications

The copper-headed steel conductor rails, shown above, of the Ringsdorff Carbon Corp., East McKeesport, Pa., help provide many economies in conductor systems for such heavy-current users as traveling cranes, ore bridges, monorails—using either a-c or d-c.

The heart of the Ringsdorff Current Conductor System—the copper-headed steel conductor rail and pantograph current collector with a graphite carbon shoe. Components, including rail hangers and joints, are available in a wide variety of sizes, with capacities up to 2000 amps, for either a-c or d-c systems

The system is simple and compact. One basic steel shape provides strength and simplifies installation. Over it is cold drawn the copper head of extruded Anaconda ETP Copper-100, in the size to meet individual current requirements. (Copper-headed conductor rail. left, 500 amps; right, 1500 amps.) Less space is needed; installation is easier than with aluminum rails.

Long life and low maintenance. The special Ringsdorff carbon graphite used in sliding contacts has an affinity to copper, putting down a film that lubricates its passage and protects the rails. Wear on the copper head is negligible over periods of 20 to 25 years. Only maintenance is replacement of carbon shoes, having an average life up to 3 years. Aluminum rails must be protected by lubrication or they will wear and pit—when out of use for a period may develop an insulating oxide film.

This is another illustration of the way the unique properties of copper are being utilized in industry to do things better—at lower cost. Anaconda has teams of specialists available to sit down with members of your organization to help select the alloys and forms of metal to solve your value analysis problems. For such technical help, see your Anaconda representative, or write: Anaconda American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ontario. 4147

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JUNE, 1961 | VOL. 53, NO. 6

Materials in Design Engineering®

FORMERLY MATERIALS & METHODS

APPLICATION OF METALS, NONMETALLICS, FORMS, FINISHES

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SPECIAL REPORT

New Directions in Materials Testing

A 32-page critical analysis of the present status and growing trends of our testing and evaluation methods 117

Strength, Stiffness, Ductility and Toughness 118

Resistance to Deterioration 125

Friction Properties and Wear Resistance 130

Color, Gloss and Texture 135

Magnetic Properties 141

Dielectric Properties 143

Semiconductor Properties 146

What's New in Materials

At a Glance 5

Two Boron Silicides 9
Excellent oxidation and thermal shock resistance to 2500 F

Plastics Assemblies Used in Electronic Wrist Watch 11
Tiny housings are first plastics used in watch movements

Powder Metallurgy Slashes Cost of Armature 12
Costs reduced 72% over previous method

Plastic Wing for a Guided Missile 13
Reinforced plastic proves superior to cast aluminum

Forgings Cost 10-20% Less 15
Automatic forging setup promises lower production costs

Other Contents 15

Materials Engineering & Design

At a Glance 103

Acetal Moldings vs Zinc Die Castings 105
An objective appraisal of their relative merits

Functional Styling with Wire 113
Formed wire assemblies have clean, functional appearance

Try Wood for Corrosion Resistance 114
Properly used, wood provides low-cost, long-life components

CONTINUED ON PAGE 3 →

Cost saving: 33%

"are you getting your metal's worth?"

The intake tubes of the Waterous Company's model CMB fire pump suck in 1250 gallons of water a minute. Rocks and other foreign matter can get sucked in too—which would have disastrous effects on the pump. A screen is needed on the intake tubes, a screen that's tough and corrosion resistant, with extra-thin vanes and a smooth surface for unimpeded water flow.

Originally these screens were fabricated from sheet brass, with the vanes brazed together. An expensive material and method for a simple but important component. **Today these screens are die cast of Zamak at a cost saving of 33%** by Twin City Die Casting of Minneapolis. The tapered vanes have a minimum wall thickness of 1/32 of an inch. Zamak is the only die casting material that can fill these thin sections and still provide the strength, corrosion resistance and smooth "as cast" surface necessary.

To find out how you can put zinc die casting to work cutting your production costs, write today to The New Jersey Zinc Company for your set of Zamak technical data books detailing the properties, use, design techniques and machining practices of the Zamak alloys. Remember—Zamak gives you more for less. Are you getting your metal's worth?

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CONTINUED FROM PAGE 1

News of Industry

Ultra Pure Materials an ASTM Topic 17
More Materials Courses 17
Refractory Metals Meeting 17
Trends in Engineering Education 19
News of Societies 19
Coming Meetings 21

Reader Service 44

Technical Literature

Suppliers' New Literature 45
Books 51
Reports 52

File Facts

Coefficient of Expansion vs Temperature 151

Prices & Supply

At a Glance 153

The Last Word

The Testing Lag 198

Other Departments

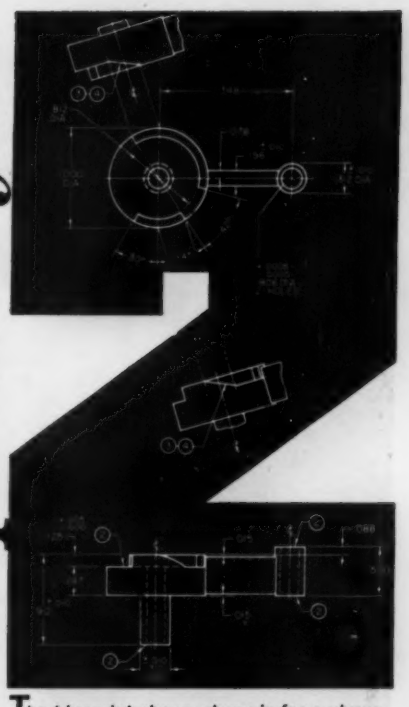
Letters to the Editor 23
Advertising Indexes:
Products Advertised 196
Advertisers 196

NEXT MONTH

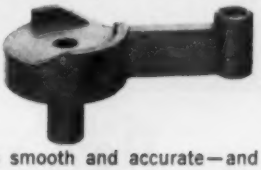
Materials for Cryogenics
Materials Failures—Causes and Cures
Lightweight Ordnance Equipment
Bonded Fibrous Sheet Can Cut Costs
Three Prize Winning Die Castings
Corrosion Resistance of Nickel Alloy Castings
Ablative Coatings
Titanium-Clad Steel Plates
Heat Treated Structural Shapes
Vacuum Hot Pressing of Zirconium

This Month's Cover *by Wayne Trapp. Photo showing specimen at instant of fracture was taken especially for us by Materials Laboratories, Westinghouse Electric Corp.*

blueprint for 2



The blueprint shown above is for a phonograph motor toggle link pressed from brass powder by American Powdered Metals Inc. for the General Industries Company. Why blueprint for two? Because it combines 2 design functions—structural support and cam surface—in a single part. Because powder metallurgy is the only economically practical way to make this part—and it could not have been achieved without design teamwork between the customer and the metal powder fabricator.



Teamwork produced a precise, intricate part assuring exact turntable speed and providing a cam surface which controls speed selection. The cam surface must be smooth and accurate—and stay that way. Holes must parallel and round to within .0005" total indicator reading. Hole centerlines must be parallel to each other within .002" T.I.R. Brass powder supplies the properties necessary for these requirements with its ideal combination of structural strength and self-lubrication.

Working together, the metal powder fabricator and design engineer make economical mass production of critical parts a reality. And we also mean "critical" in the sense that a whole is no better than the quality of its most prosaic part. For more information about the design, application and advantages of nonferrous metal powder parts, write today to The New Jersey Zinc Company for your copy of "Designing For Pressed Brass and Nickel Silver Parts."

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DEVELOPERS OF BRASS & NICKEL SILVER POWDERS SETTING TODAY'S STANDARDS

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How Nickel Stainless Steel "lightweights" curb Philadelphia subway costs by $6.4 million

Commuters using the Market-Frankford elevated subway line in Philadelphia are smiling these days. So are transit authorities. That's because the line's new subway cars are the most modern in design for passenger comfort . . . and the most economical the city could buy.

Compared to competitive subway cars, during a 35-year depreciation period these new Nickel Stainless Steel cars will:

Operate on $2.4 million less power. They are solidly constructed, yet are so light they run on 12% less electric power than conventional cars based on the same specifications but fabricated from other materials.

Require $4 million less maintenance. Designed and built from Nickel Stainless Steel by The Budd Company to specifications set by the City of Philadelphia and the Philadelphia Transportation Company, these cars need no painting and virtually no exterior maintenance . . . because Nickel Stainless Steel resists corrosion and retains its handsome finish.

And because they are the lightest cars for their size ever built, they:

Help cut running time by 6 minutes. Thanks to the excellent combination of stiffness and high strength found in Nickel Stainless Steel, their thinner-gauge body shells reduce costly dead-weight and make it easier for powerful motors to increase acceleration and braking rates.

Can Nickel alloys save you money? Alone or with other elements, Nickel improves hundreds of alloys, making possible almost any desired combination of properties for meeting specific service demands...while reducing long-term costs. For a guide to information about Nickel, its alloys, and their industrial applications, send for our catalogue of publications. Ask for List "A".

The International Nickel Company, Inc.
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Inco Nickel

Nickel makes alloys perform better longer

For more information, turn to Reader Service card, circle No. 363

Titanium-clad steel plates are now available in thicknesses up to 1¼ in., with a maximum cladding thickness of 3/16 in. Plate sizes range from 4 to 8 ft wide and 12 to 24 ft long. Plates are clad by hot rolling layers of titanium onto steel plates. Surfaces are kept clean by purging steel and titanium in argon gas before rolling.
Source: Lukens Steel Co., Coatesville, Pa.

A new class of silicone fluids has been developed. Nitrile groups in the fluids are said to give them high polarity which results in such properties as solvent resistance, limited electrical conductivity and high dielectric constant. The fluids have a dielectric constant ranging from 3 to 20 at 60 cps, compared to 2.5 to 3.0 for standard silicone fluids. Potential uses: base stocks for solvent resistant greases and coatings, and additives for plastics.
Source: General Electric Co., Silicone Products Dept., Waterford, N. Y.

Large single crystals of zinc are available for nuclear and electronic applications. The crystals weigh 30 lb and are 5 in. in dia by 5 in. high. Price is $100 per lb.
Source: Semi-Elements, Inc., Saxonburg Blvd., Saxonburg, Pa.

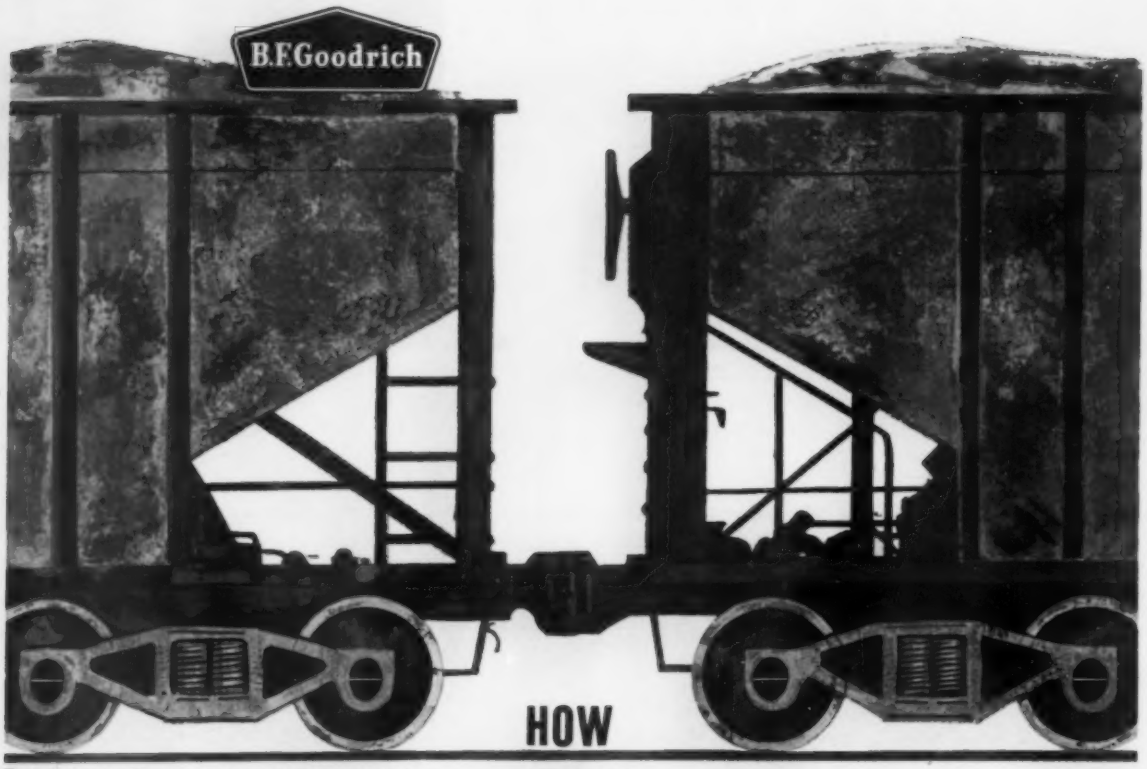
A new air drying primer for metals, described as a resinous, modified styrene-butadiene latex, has excellent resistance to water and salt spray. Metals coated with the primer have shown no traces of corrosion after 100 hr of continuous exposure to salt spray. The primer dries to a clear, non-tacky film that has high tensile strength.
Source: Goodyear Tire & Rubber Co., Chemical Div., Akron 16, Ohio.

A filament wound glass-epoxy tubing is said to have burst strengths that exceed those of conventional G-10 grades of glass-plastics tubing by about 3 to 1. The new tubing is recommended for switchgear, high voltage fuse tubes and other parts requiring high burst strength.
Source: Spaulding Fibre Co., Inc., 310 Wheeler St., Tonawanda, N. Y.

A new tool steel can be heat treated to a tensile strength of over 350,000 psi. The developer says the steel has good ductility and impact strength at this high strength level. Other advantages include good machinability and low hardening temperature.
Source: Carpenter Steel Co., 101 W. Bern St., Reading, Pa.

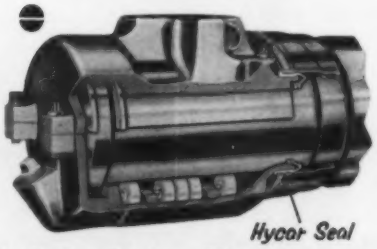
A rigid high temperature adhesive with high electrical resistance and low thermal conductivity can be used at temperatures up to 1000 F. The new material is expected to be used as a structural adhesive and for coating and encapsulating electronic parts. Composition has not been revealed.
Source: Radiation Applications Inc., 36-40 37th St., Long Island City 1, N. Y.

A new, self-extinguishing urethane foam has been introduced recently. Fire resistance of the rigid foam is obtained by building a high chlorine content into the polymer, rather than by using additives. The material is classed as self-extinguishing in accordance with ASTM D1692 and has a burning rate of 0.75 in. per min by



Clevite sealed sleeve cartridges using an oil seal of Hycar are manufactured by Cleveland Graphite Bronze division of Clevite Corporation, Cleveland, Ohio. B.F.Goodrich Chemical Company supplies the Hycar nitrile rubber for molding into seals.

HOW HYCAR PUTS A SEAL ON "HOT BOX" ELIMINATOR



Hycar Seal

Inspection of the working parts of this sealed sleeve bearing cartridge is necessary just once every nine years, according to the manufacturer. Beyond this, the only maintenance needed to assure against freight car "hot boxes" is an annual check of oil levels. Fitted against the journal inside the housing is a positive oil seal made of Hycar nitrile rubber which permanently retains the lubricant.

The manufacturer says, "Without question, there isn't a seal that compares with this one." He's referring to the outstanding resistance to abrasion, to oils and other hydrocarbons and to heat offered by Hycar. Years of service under these tough conditions won't affect the resilience or effectiveness of these seals. The properties of Hycar solve a tough molding problem, too.

Here's another example of how Hycar improves present products, sometimes makes possible entirely new products for new markets. Can Hycar help solve your problem? Write for information—Department MI-3, B.F.Goodrich Chemical Company, 3135 Euclid Avenue, Cleveland 15, Ohio. In Canada: Kitchener, Ontario.

B.F.Goodrich Chemical Company

a division of The B.F.Goodrich Company

Hycar Rubber and Latex

For more information, turn to Reader Service card, circle No. 352

ASTM D757. The new foam also passes the self-extinguishing requirements of Underwriters Laboratories Bulletin, Subject 94. It has a k factor of 0.1 Btu/hr/sq ft/°F/in. which is reported to be extremely stable on aging of cut specimens. The developer says the new foam system is competitive in cost with fluorocarbon-blown polyether systems.

Source: Hooker Chemical Co., 704 47th St., Niagara Falls, N. Y.

Rolled structural shapes made from quenched and tempered alloy steels are now available. The new shapes are heat treated to design strengths as much as three times that of structural carbon steel. Furnished in standard I-beams, channels and angles, and in lengths up to 40 ft, the shapes are produced from such steels as T-1 and T-1 type A constructional alloy steels, 9% nickel steel for cryogenic uses, and HY-80 naval armor steel.

Source: United States Steel Corp., 525 Wm. Penn Pl., Pittsburgh 30.

A newly developed colloidal alumina can be used to improve the heat resistance and strength of a number of engineering materials. The alumina disperses and swells in water to form a stable colloid. Tests show the colloid 1) increases the thermal stability of glass fibers and firebrick coatings, 2) makes synthetic fabrics water repellent and stain resistant, and 3) strengthens paper, ceramics and foam rubber. Currently available in developmental quantities, the material sells for $3.50 per lb.

Source: E. I. du Pont de Nemours & Co., Inc., Industrial and Biochemicals Dept., Wilmington 98, Del.

A new flame-retardant epoxy resin is designed for hot melt castings and dry lay-up laminating systems. A laminate made of the resin was self-extinguishing in 7 sec when tested in accordance with ASTM D635. Combined with aromatic amine or anhydride hardeners, the epoxy forms cured systems that have physical, electrical and chemical properties similar to those of conventional epoxies. The resin is semi-solid at room temperature and requires only moderate heating to become a readily pourable liquid.

Source: Union Carbide Plastics Co., Div. of Union Carbide Corp., 270 Park Ave., New York 17.

A new aluminum-silicon casting alloy is said to have high yield strength, good dimensional stability, and good fatigue and shock resistance. Tests show the alloy is dimensionally stable to 0.00001 in. per in. after stress relieving at 700 F. The aluminum alloy is particularly suited for castings used in computers, aircraft, missile guidance systems and electronic equipment. (More details in a forthcoming issue.)

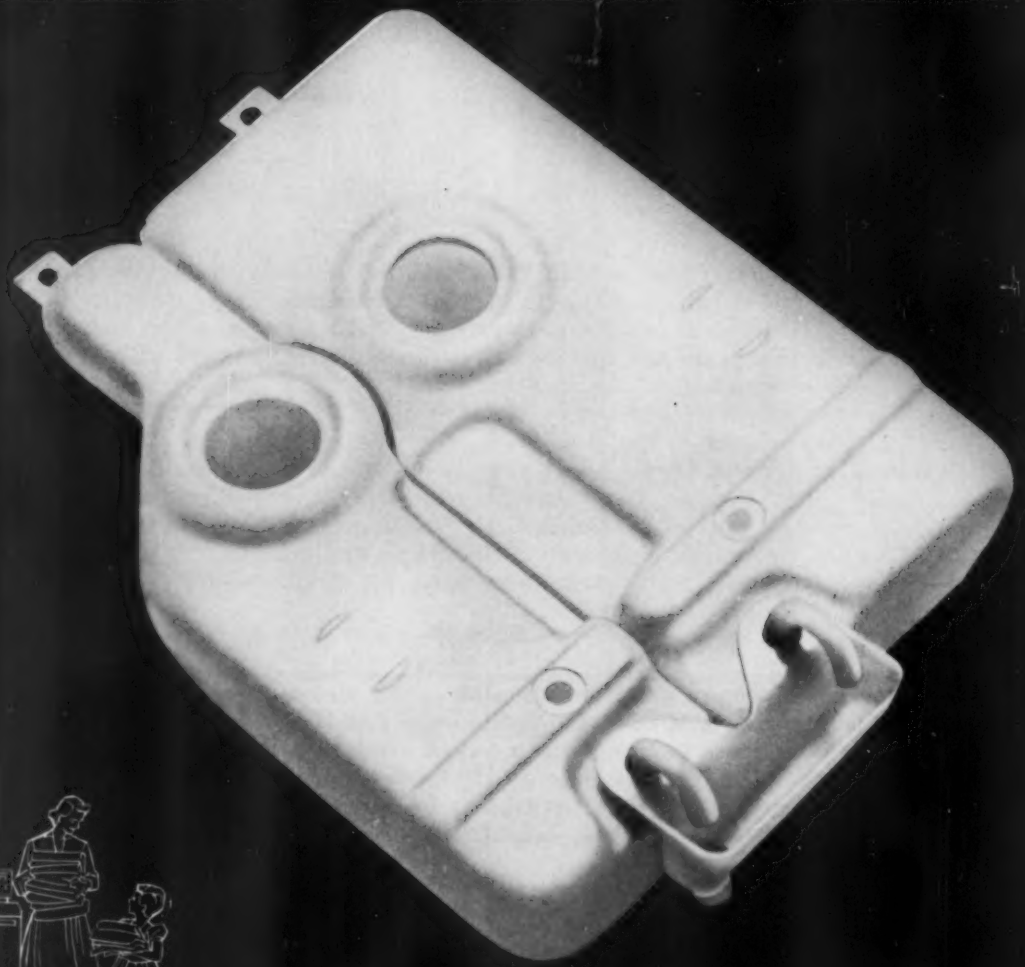
Source: William J. Jobbins, Inc., Aurora, Ill.

A series of asbestos-phenolic molding compounds are recommended for ablation applications. Two grades are available: a general purpose compound for use up to 3500 F and a high temperature compound for use up to 6000 F. Some typical applications are insulations for re-entry vehicles and rocket motors.

Source: U. S. Polymeric Chemicals, Inc., Canal & Ludlow Sts., Stamford, Conn.

Turn to page 9 for more "What's New in Materials"

CELANESE POLYMER COMPANY



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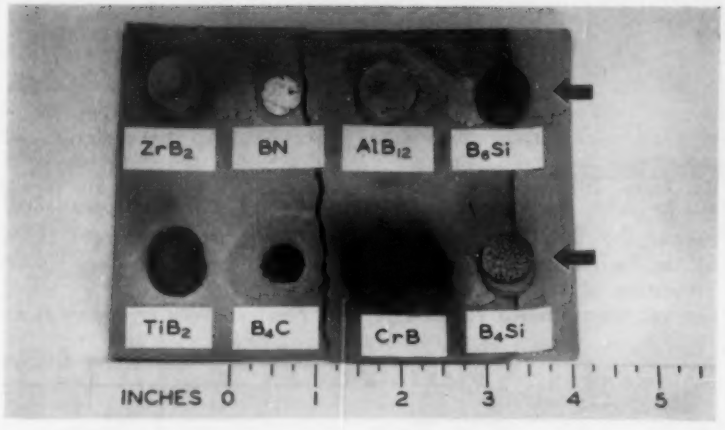


***After 2500 F** exposure boron silicides at far right are relatively unaffected compared with six other high boron compounds.*

Two Boron Silicides

have excellent oxidation resistance up to 2500 F

by Dr. E. Colton, *Research Div., Allis-Chalmers Mfg. Co.*

■ Two new ceramic-like materials, high in boron content, have been developed for use at high temperatures. For ceramics they are low in density, and they have excellent thermal shock resistance and outstanding oxidation resistance at temperatures up to 2500 F. The materials are hexaboron silicide (B_6Si) and tetraboron silicide (B_4Si); development of the latter was first announced last year (see M/DE, June '60, p 6).

The high boron contents (60 and 70% for B_4Si and B_6Si, respectively) should make the materials suitable for use in nuclear reactors as neutron control sources, shielding structures and burnable poison.

The materials are available as black, free-flowing microcrystalline powders (about 70μ in size) with a bulk density of 37 lb per cu ft. Price depends on purity, and ranges from 12¢ per gm or $50 per lb for highest purity grades, to 8¢ per gm or $35 per lb for lower purity materials. The materials are available in pound quantities; production can be increased rapidly to meet demand.

Fabricated by powder metallurgy

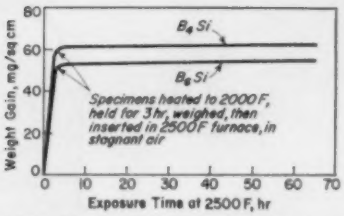
The materials can be fabricated by conventional powder metallurgy techniques: they can be cold pressed readily without binders; they can be hot pressed; they can be slip cast and extruded.

One of the most interesting characteristics of boron silicides are their sinterability in air. If the material is cold pressed at about 10,000-20,000 psi and sintered in air at about 2000 F, the formation of oxide bonds provides a body strong enough to be machined with ordinary machine tools (though carbide tools are recommended). The machined part is then refired to 2500 F in air with virtually no shrinkage, forming an extremely hard, dimensionally stable body.

Oxidation, shock resistance

The accompanying curves show weight gain after 65 hr at 2500 F for specimens of both silicides.

Pressed and sintered *parts are shown here. Parts can also be shaped by slip casting or extruding.*



Oxidation resistance *of the two new boron silicides at 2500 F. Initial increase in weight is due to formation of amorphous protective oxide layer.*

During sintering the materials absorb oxygen, forming a protective coating of an amorphous phase, probably a silicon-boron-oxygen glass, which prevents further oxidation. Thus, the materials can be used under conditions that severely degrade boron carbide, as well as other borides.

Tetraboron silicide is somewhat unstable at high temperatures disproportionating to hexaboron silicide and silicon; consequently most work has been done with hexaboron silicide, some properties of which are given in the accompanying table. As indicated by the limited data, the ceramic properties of the material have not yet been studied completely.

Bodies of oxide-bonded hexaboron silicide have been prepared with a density of about 106 lb per cu ft. Strength depends on sintering time; after sintering for 24 hr at 2500 F in stagnant air, bending strength is about 12,000 psi at room temperature, 10,500 psi at 2000 F.

Thermal shock resistance is exceptionally good. No cracking has been observed after 50 cycles between 2000 F and room temperature in air. Further, no cracking occurs when the material is heated to 2000 F, then quenched in water.

PROPERTIES OF HEXABORON SILICIDE

Form ➡	Oxide-Bonded Black Powder	Orthorhombic Crystals
Density, lb/cu ft	106-131	151.6
Melting Point, F	[a]	3500
Coef of Ther Exp (77-1800 F), 10^{-6} per °F	3.5	—
Vol Res, ohm-cm	Insulator	0.2
Knoop Hardness	—	1900-2400
Mod of Rupture, 1000 psi[b]		
At 77 F	13.0	—
At 2000 F	10.8	—
Abrasion Resistance	~SiC	~SiC

[a] No melting when subjected to argon-restricted plasma jet. Material may vaporize.
[b] Strength is dependent on sintering time; values given are for 24-hr sintering at 2500 F.

Composition adjustable

The Allis-Chalmers process for preparing boron silicide consists of reacting elemental boron with silicon under carefully controlled conditions. Products are better than 95% pure and contain very little free silicon, e.g., typical lots contain 0.5-1.5% free silicon. Free silicon contents of up to 15% can be obtained if desired.

For more information, circle No. 600

Pure vanadium ring, 14 in. o.d., weighing 60 lb, is believed to be the largest centrifugally cast vanadium component produced commercially. Ring was cast by Oregon Metallurgical Corp., Albany, Ore.

For more information, circle No. 601

Plastic-encased *circuitry drives the tuning fork, shown being installed. Each small coil, at the bottom of both cases, is wound with 300 ft of 0.0006-in. dia wire. The circuit assembly can be removed and replaced as a unit.*

Plastics Assembly in... Electronic Wrist Watch

by W. C. Bennett, *Vice President and Director of Research Engineering, Bulova Watch Co.*

■ Two tiny housings for all the components of a microminiature power circuit are the first plastics parts to be used in wrist watch movements.

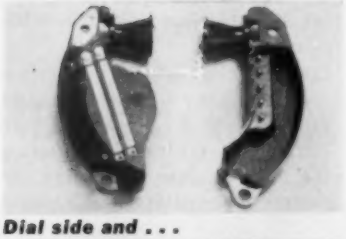
The two-piece assembly, only 0.5 cu in. in size, supports and encloses a transistor, power cell, two small coils, and all connecting components and leads.

The power circuit is used in Bulova Watch Co.'s "Accutron" electronic time piece. In operation, the circuit generates pulsed current that vibrates a small tuning fork positioned between the coils. The fork oscillates at exactly 360 cps to drive the watch mechanism.

Housings transfer molded

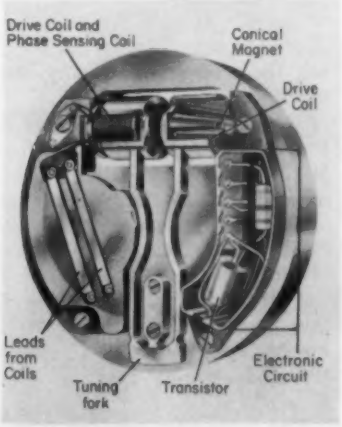
The chassis assembly is transfer molded from glass-filled diallyl phthalate resin. Thermosetting DAP was selected because of its: 1) high dielectric strength; 2) good moisture, solvent, acid, alkali and fungus resistance and 3) good tension, compression and impact resistance. In addition, its excellent moldability is needed to hold the critical dimensions of the assembly. For example, the walls of the two coil bobbins, integral to the chassis, are 0.004 in. thick.

In tests, the molded parts withstood temperatures from −95 to 212 F without damage. The compound, supplied by Mesa Plastics Co., can be molded and cured in about 1 min. It does not stick or shrink during processing. Food Machinery and Chemical Corp. produces the resin.

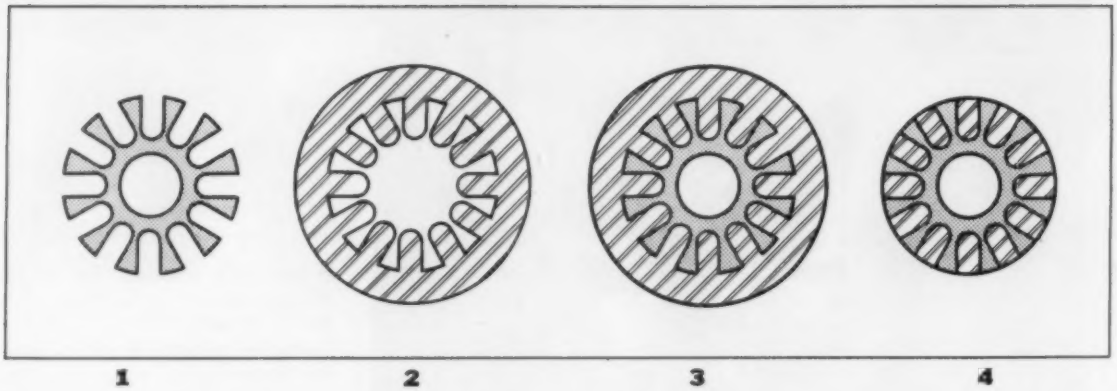


Dial side and . . .

. . . back of the cases. *Even though the case is only ⅞ in. high, a transistor, a resistor and leads fit into the right-hand shell. The power cell is positioned under the left case.*



Basic components *of the electronic watch, shown from the front. The tuning fork tines are vibrated by the magnetic fields of the drive coils. The DAP plastic encased electronic components flank the tuning fork.*



1 2 3 4

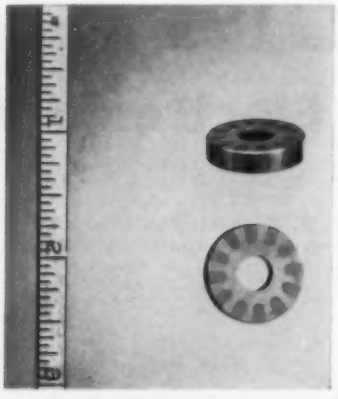
Core *is pressed of prealloyed bronze powder.*

Outer ring *is pressed of steel powder and sintered.*

Core and ring *are internested and the green core sintered, its resulting expansion firmly bonding the assembly.*

Outer ring *is machined off to produce the armature having alternating magnetic and nonmagnetic sections.*

Powder Metallurgy Slashes Cost of Armature



This method costs 72% less than previous method of staking segments into milled slots

■ The process illustrated above is being used by Kwikset Powdered Metal Products, Anaheim, Calif. to make a polarizer for a d.c. motor. It takes advantage of the controlled expansion that can be achieved in sintering a bronze powder. Sintering the bronze core in place has little effect on the already-sintered steel ring but causes the radiating lugs on the inner ring to lock firmly against the surfaces of the slots in the steel outer ring.

Clearance between the two parts before the final sintering is about 0.001 in. The sintering requires 15 to 20 min at 1450 to 1600 F. Control over expansion or shrinkage is obtained primarily by varying the compacting density during the pressing operation.

The method was developed by Eugene R. Andreotti and John Mikitka, now with Kwikset, and is covered by U. S. Patent 2,913,819.

The part, about ⅞ in. o.d. (as finished), is made for AiResearch Mfg. Div. of The Garrett Corp. It won an Award of Distinction in this year's "Nonferrous Metal Powder Part of the Year" competition sponsored by The New Jersey Zinc Co.

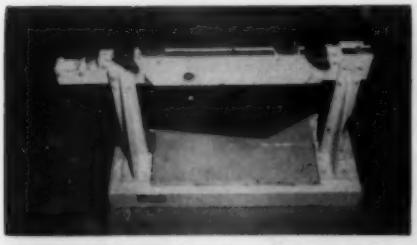
The large cost savings offered by the powder metallurgy technique result from the elimination of machining and staking or peening operations. Conventional armature construction for small, fractional horsepower motors consists of milling slots in a magnetic disk, inserting nonmagnetic segments into the slots, and retaining them in place by peening core material over their ends.

In addition to cost savings, the powder metallurgy method is expected to provide greater reliability, since staked segments are more likely to break loose at high rotational speeds.

The inventors of the method also suggest the possibility of making the inner core of ferromagnetic material and the outer ring of brass; in such a case the controlled *shrinkage* of the brass would be used to obtain the bond between core and outer ring.

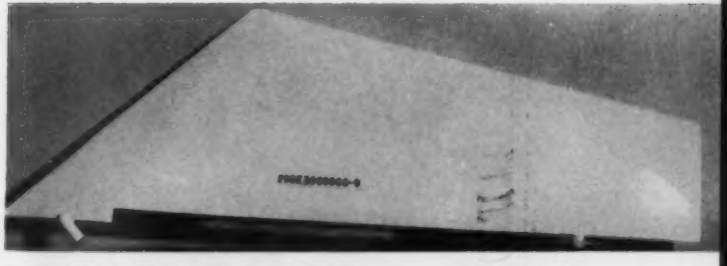
1 Molded half shell *in position in the female die. The impression plate that formed the internal cavity is at the back. Before molding, the glass cloth was epoxy impregnated and partially polymerized.*

2 Antenna assembly *is securely bonded into the mated half shells with a modified epoxy resin adhesive.*



3 Trimming and drilling *the incompleted assembly. Routing of attachment slots is also done while the wing is in this fixture.*

4 Proof-loading test *measures wing tip deflection under simulated flight loads.*



6 Finished wing *is enameled with an epoxy without using a primer. Four wings of this type are used on each missile.*

Plastic Wing for a Guided Missile

by P. J. Palmer, Jr. and D. S. Blevins,
Brunswick Corp., Marion, Va.

5 Dimensional accuracy *is checked in a rigid fixture. Thickness and flatness tolerances are very close.*

■ The Bullpup B missile is now using a fiberglass-reinforced epoxy wing which is physically superior to the centrifugally cast aluminum wing used on the missile's predecessor, Martin Co.'s Bullpup A.

One of the major advantages of using a plastic for the wing is that it offers no interference with the guidance antenna encapsulated within the wing. Previously, the antenna had to be mounted in a channel on the surface of the metal wing.

The high temperature plastics system, developed by Brunswick, withstands operating temperatures up to 500 F while maintaining low load deflections.

The epoxy wing is easily fabricated to precise dimensions. Finishing is greatly simplified because the wettability of the resin eliminates resin-starved and pitted areas.

Each wing is laminated and bonded in two sets of matched molds. Each half shell mold consists of a die which forms the outside and an impression plate which forms inside cavities for the antenna.

WHICH OF THESE STAMPINGS COSTS LESS WITH PRECISION STEEL?

All of them, as a matter of fact. The design requirements of the finished parts may—or may not—call for closer than standard tolerances. But in an intricate, high-speed operation, a variation of 0.003" could result in costly production problems—frequent delays, constant tool adjustment, a high percentage of rejects, etc.

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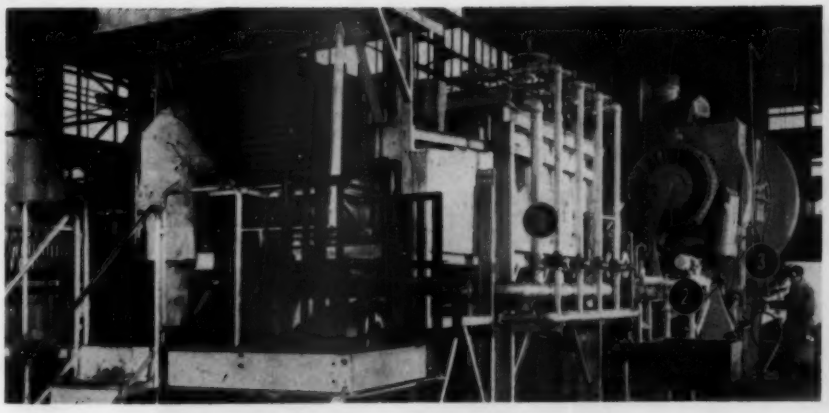

***Automatic forging unit** has billets fed into furnace (1). At discharge end (2) billet is automatically conveyed to a 2500-ton Erie Foundry Press (3) where it is fed through a 4-stage die. A trimmed, hot coined tractor link is discharged from the press and conveyed to a tote pan.*

Forgings Cost 10-20% Less . . .

. . . as a result of a new automatic forging press

■ An automatically produced press forging offers users a 10 to 20% cost reduction over manual forging costs, yet is comparable both in strength and dimensional tolerances to manually produced forgings. The cost reduction is made possible by the high production rate and decreased labor cost of the automatic unit.

Developed over a two year period by the AmForge Div., American Brake Shoe Co., Chicago, Ill., the automatic press forging complex shown above will:

1. Handle the entire forging process, from billet heating to trimming and hot coining, without a single manual handling operation.

2. Require half the man power usually employed in normal hammer or press operations.

3. Increase production rate by a minimum factor of two.

AmForge Div., does not plan to license the system.

Best for simple parts

The automatic press is most effective when used to produce fairly symmetrical forgings which do not require deep die cavities that would increase the possibility of forgings sticking in a die cavity. The same sticking problem is encountered in manual forging but is a more serious malfunction in a unit which can produce up to 1200 parts per hr.

As the press is now constituted, 10 to 12 lb is the maximum weight that can be automatically forged. Maximum billet size is approximately $10\frac{1}{2} \times 4\frac{1}{2} \times 2\frac{5}{8}$ in., for the four-station die. Billet size can be increased by forging in a three-station die and conveying the forging to an automatic trim press. Radical increases in billet size are possible but the in-press transfer system would have to be changed.

AmForge Div. anticipates that high volume items such as track links, conveyor belt links, automotive gears and high pressure valves and fittings can be economically produced on the automatic press.

Track links: a case history

The advantages of an automatic press forging system can be demonstrated by the track link shown in the accompanying photo-

(continued on p 165)

MORE WHAT'S NEW IN MATERIALS

Plastics laminates for electronic parts 165
Electrical explosions shape exotic metals 166
Neoprene-base paint for outdoor uses 168
New casting method cuts piece cost 50% 170
Flexible polyethylene competes with vinyls .. 172
Beryllia heat sinks 174
Large steel forging 174
Vinyl surfacing mat is abrasion resistant ... 176
Clear silicone for encapsulating, potting.. 178
Galvanized sheet has improved paintability .. 180
Rubber liners protect metal against abrasion . 182
New organic coating 184
Other news 184

SILICONE NEWS from Dow Corning

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STRIP MOLD

POUR RTV

FINISHED PART

SILASTIC RTV makes precision molds in minutes

These photos illustrate how easily you can produce exact molds and prototypes in a matter of minutes, instead of days or weeks. The medium: Silastic® RTV, the fluid silicone rubber that vulcanizes at room temperature.

The beauty of this silicone rubber: you simply add catalyst, mix and pour Silastic RTV into or around the object you wish to reproduce. The fluid rubber flows into the tiniest crevices, fills voids in even the most intricate parts, and vulcanizes without heat to form a durable accurate mold.

The cured mold easily withstands 500 F temperatures. You can use it to cast a variety of plastics or low-melting alloys. Release is no problem. The firm but flexible mold made of Silastic RTV strips easily from metal, wood, plaster, plastic and most other materials. Store the mold; it doesn't change on aging (crack or check) and you can make exact reproductions months, or even years later.

Using Silastic RTV is the quick and economical method of preparing duplicates that match the original in every detail. May we assist you in adapting this new design and development tool to your special needs? Write on your letterhead for *free sample* and how-to-use information. Address Dept. 7418a.

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For more information, turn to Reader Service card, circle No. 360

News OF INDUSTRY

Ultra Pure Materials a Major ASTM Meeting Topic

About 25 of the more than 125 papers to be presented at the annual meeting of the American Society for Testing Materials will be of direct interest to materials scientists and engineers. The meeting will be held in Atlantic City, N. J., June 25-30.

Materials sciences papers

The Materials Sciences Div. will sponsor two sessions on the major effects of minor constituents on the properties of materials, including metals, ceramics, organics, liquids, and gasses. Among the papers, to be presented are: *Impurity Effects in High-Purity Metals*, L. L. Wyman, G. A. Moore, National Bureau of Standards; *The Effect of Impurities on the Properties of Ceramic Materials*, I. B. Cutler, University of Utah; *Major Effects of Minor Constituents—Role in Organic Material Structures*, J. F. Lontz, E. I. du Pont de Nemours & Co., Inc.; and *The Problem of Gas Purity in Plasma Research and Technology*, S. J. Buchsbaum, Bell Telephone Laboratories, Inc.

Metal topics

In the field of metals, topics include: 1) fatigue damage in steel and aluminum; 2) fatigue properties of coated and uncoated molybdenum; 3) effects of impurities on the endurance of steel wire rope; 4) designing with metals for low temperature service; 5) improving analytical methods for determining the effects of very small constituents in metals; 6) evaluating metallic materials in design for low temperature service; 7) high temperature creep and rupture of copper, nickel and various alloys in helium atmosphere; 8) stress corrosion evaluations of various steels; 9) elevated temperature compression testing of sheet magnesium and nickel-chromium alloy; 10) evaluating the properties of nonferrous metals, such as titanium, and molybdenum; and 11) erosion and cavitation processes.

The effects of impurities on the properties of plastics and ceramics, and radiation effects on refractory fuel compounds and other rector materials are among the other topics at the meeting.

Twin highlights of the meeting will be: the Marburg Lecture by Prof. Bruce Chalmers, Harvard University, on the subject of nucleation and growth of ice crystals; and the Gillett Memorial Lecture by A. B. Kinzel, Union Carbide Corp., on the nature, purpose and use of specifications.

More Materials Courses Offered This Summer at Penn State and MIT

Three additional summer courses in materials engineering and science have been announced by Pennsylvania State University and Massachusetts Institute of Technology. Previously announced courses have been described in M/DE, Mar '61, p 22 and May '61, p 23.

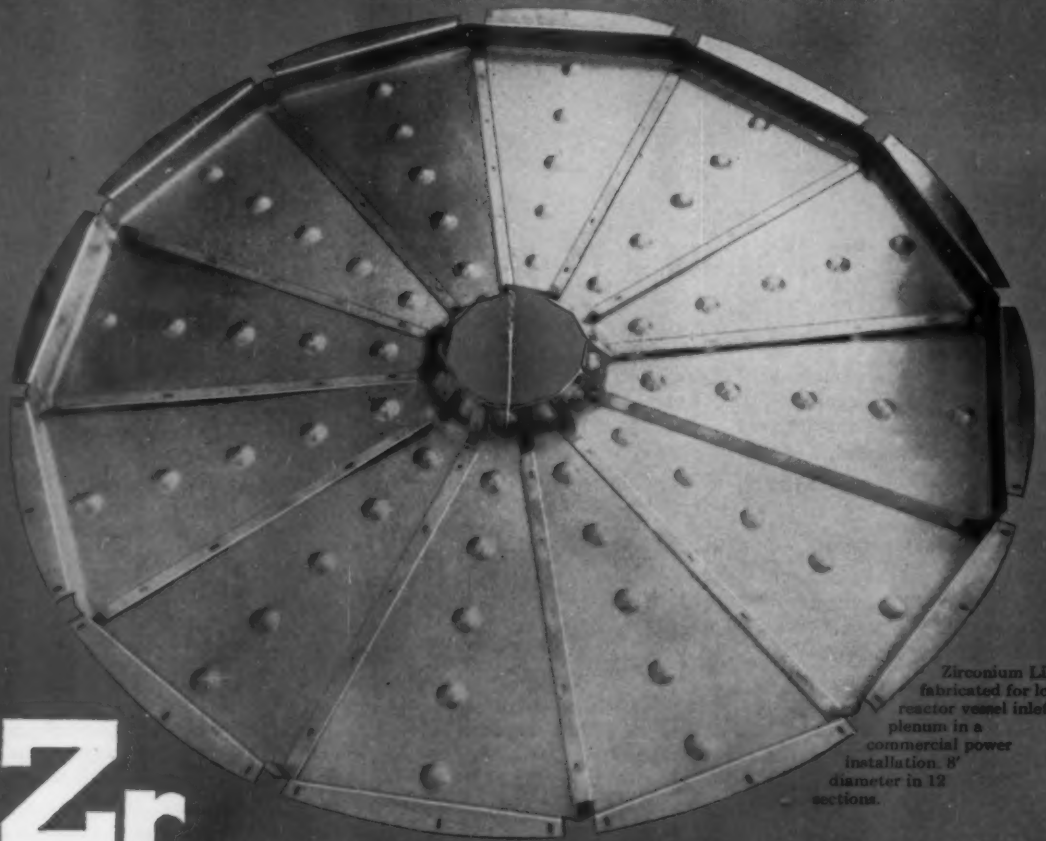
Pennsylvania State University—*Electrical Contacts Seminar (June 11-16)* will present the latest information on the design and construction of static, sliding and commutation, and arcing contacts as well as basic electrical contact theory. Topics will include: metal tarnishing, contact bounce, mechanical loading of static contacts, wear and noise, film studies, and resistance variations in sliding and arcing contacts.

Massachusetts Institute of Technology — *Nondestructive Testing (June 26-30)* will be a lecture program dealing with the most important testing methods including magnetic particle inspection, eddy currents, x-rays, ultrasonics and fluid penetrants. In each case the lectures will cover theory, recording and interpretation, and current laboratory and field practices. The course is primarily for graduate engineers and metallurgists. *Advanced Topics on Solid State Masers (July 24-28)* will be an intensive presentation of recent experimental and theoretical advances in solid state maser and laser technology. Topics will include: high frequency traveling wave masers; cross relaxation; electron nuclear double resonance phenomena; optical pumping; and technology of solid state lasers.

Forming Refractory Metals MPIF Topic

"Powder metallurgy has much to offer in the fabrication of titanitum, a material that is costly and difficult to shape by ordinary

CATCHES MOLTEN URANIUM



Zirconium Liner fabricated for lower reactor vessel inlet plenum in a commercial power installation. 8' diameter in 12 sections.

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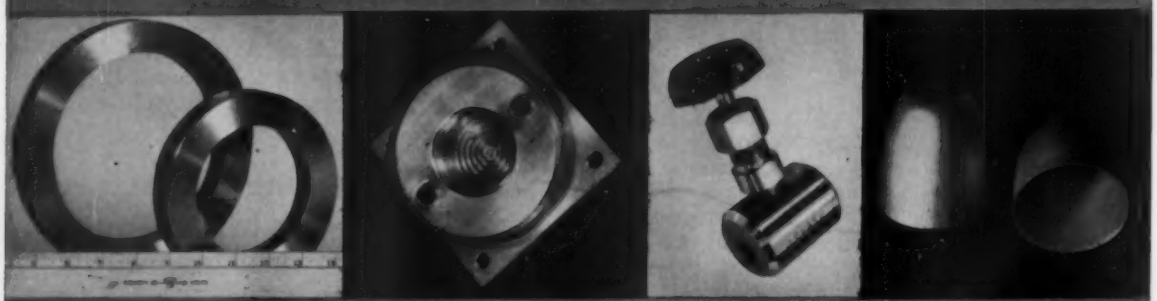

Scatter Rings Used in Radiation Research

Zirconium Metal Cathode

Valve Resists Severe Corrosion

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For more information, turn to Reader Service card, circle No. 325

means," E. P. Weber, Clevite Corp., told the recent annual meeting of the Metal Powder Industries Federation.

Also discussed were: new developments in high temperature sintering furnaces that operate at temperatures up to 5000 F; a new approach to the study of powder compaction; and the effects of fabricating methods on the electrical and magnetic properties of metal powders.

One highlight of the meeting was the awarding of the first MPIF Powder Metallurgy Pioneer Award to R. P. Koehring, who recently retired from Delco Moraine Div., General Motors Corp.

Trends in Engineering and Education: Freshman Enrollment Still Dropping

▸ Enrollment in freshman engineering classes has again dropped below that of the previous year. Although this trend has continued for the last four years, the U. S. Office of Education reports that the rate of decrease is slowing.

A total of 67,600 freshmen enrolled in engineering courses last fall as compared with 67,700 in 1959. The small decrease may indicate that the efforts of the engineering profession to stimulate interest in engineering among high school students is having some success.

▸ In contrast to freshman classes, enrollments for graduate degrees continue to climb steadily. The Office of Education reports that the number of students enrolled for master's degrees increased from 29,700 in 1959 to 31,200 this fall. Doctorate student bodies increased 14.3% from 5600 to 6400, in the same period.

▸ During 1961-62, more than 1700 graduate students will be assisted in their scientific, mathematics and engineering studies by two National Science Foundation fellowship programs.

Each Fellow will receive a basic 12-month stipend of $2200 supplied by NSF. In addition, the schools will receive a standardized cost-of-education allowance for each Fellow.

Of the 1725 graduate awards, 425 were made in physical sciences, including a number of interdisciplinary fields, and 201 were made in mathematics. The rest were granted in the life and social sciences.

Applications are first screened by the approximately 160 sponsoring colleges and universities. The final selection is made by 50 eminent scientists, appointed by the National Academy of Sciences–National Research Council.

▸ North Carolina State College's School of Textiles is "revamping its curriculum away from the 'how-to-do-it' approach toward more emphasis upon the basic physical sciences, textile technology and the humanities" a spokesman says.

▸ Engineers' salary levels rose approximately 5% per year between 1958 and 1960, according to a survey made by the Engineers Joint Council.

The overall median salary is now $9600. An earlier survey made in 1953 found the median pay at that time to be $6500.

The survey findings were published recently by the Council's Engineering Manpower Commission. The report called: *Professional Income of Engineers-1960* is available from EJC, 29 W. 39 St., New York City 18, at $3 per copy.

▸ Establishment of a separate civil service classification system for scientists and engineers is the purpose of a bill recently introduced by Rep. V. L. Anfuso of N. Y. It is intended to improve the government's competitive position for recruiting and maintaining qualified technical staffs.

The bill would establish a 10-grade "Professional Engineering-Scientific" schedule for professional-level engineers, physical scientists and mathematicians in the government, with salaries starting at $6400 a year, and going up to $20,000.

News of Societies

Aluminum Assn. has elected the following 1961 officers: president—J. W. Douglas, Republic Foil Inc.; chairman—M. M. Anderson, Aluminum Assn.; reelected honorary chairman—A. V. Davis.

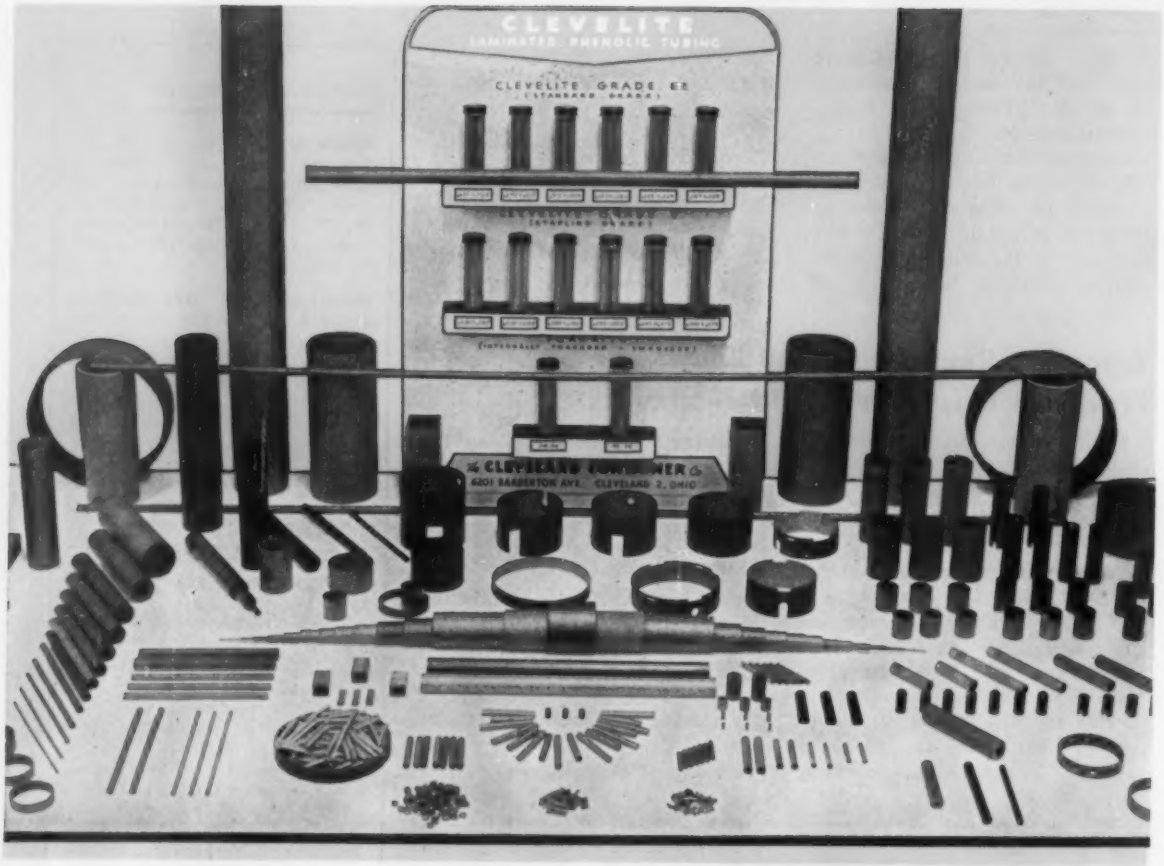
American Hot Dip Galvanizers Assn. has elected the following officers: president—W. M. Boyles, Boyles Galvanizing and Plating Co.; 1st vice-president—T. R. Gregory, Thomas Gregory Galvanizing Works; 2nd vice-president—C. Hawthorne, Metal Services Inc.; reelected secretary-treasurer—C. E. Perry; technical director—J. R. Daesen.

American Powder Metallurgy Institute, Metal Powder Industries Federation, has established a section in Cleveland and has elected the following officers: chairman—C. R. Halverstadt, Kirkwood Carbon Corp.; 1st vice-chairman—J. Merrill, Clevite Research Corp.; 2nd vice-chairman—J. J. Millen, General Electric Co.; treasurer—V. Kalan, Cleveland Graphite Bronze Div., Clevite Corp.; recording secretary—T. P. Herbell, Case Institute of Technology; corresponding secretary—S. R. Crooks, Republic Steel Corp.

American Society for Metals has granted the following awards: Albert Sauveur Achievement Award—Dr. C. L. Clark, Timken Roller Bearing Co.; William Hunt Eisman Medal—R. B. Heppenstall, Midvale-Heppenstall Co.

American Welding Society has elected the following officers: president—A. F. Chouinard, National Cylinder Gas Co.; vice-president—J. Bland, General Electric Co.; directors-at-large—J. E. Dato, Linde Co.; T. E. Jones, Precision Welder and Machine Corp.; A. N. Kugler, Air Reduction Sales Co.; E. C. Miller, Oak Ridge National Laboratory.

Metallurgical Society of AIME has elected the following officers: president—J. S. Smart, Jr., American Smelting & Refining Co.; division chairman—Extractive Metallurgy, R. C. Cole, White Pine Copper Co.; Metals, J. H. Jackson, Battelle Memorial Institute, Iron and Steel, Dr. G. Derge, Carnegie Institute of Technology.



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Coming Meetings

AMERICAN SOCIETY OF MECHANICAL ENGINEERS, annual meeting. Los Angeles. June 11-15.

PLASTICS IN PACKAGING, Society of Plastics Engineers, regional conference. Montreal. June 14.

INTERNATIONAL POWDER METALLURGY CONGRESS. Reutte, Austria. June 20-24.

AMERICAN SOCIETY FOR TESTING MATERIALS, annual meeting. Atlantic City, N. J. June 25-30.

VACUUM METALLURGY, Sponsored by American Vacuum Society and New York University. New York City. June 26-27.

NATIONAL SOCIETY OF PROFESSIONAL ENGINEERS, annual meeting. Seattle. July 4-7.

SEMICONDUCTOR CONFERENCE, American Institute of Mining, Metallurgical and Petroleum Engineers. Los Angeles. Aug 30-Sept 1.

AMERICAN CHEMICAL SOCIETY, national meeting. Chicago. Sept 3-8.

ENGINEERING MANAGEMENT CONFERENCE, American Society of Mechanical Engineers and American Institute of Electrical Engineers. New York City. Sept 14-15.

HIGH TEMPERATURE CERAMIC-ON-METAL PROCESSES CONFERENCE, American Ceramic Society. Columbus, Ohio. Sept 20-23.

STEEL FOUNDERS' SOCIETY OF AMERICA, 59th fall meeting. Hot Springs, Ark. Sept 24-26.

PROCESS INDUSTRIES CONFERENCE, American Society of Mechanical Engineers. Houston, Texas. Oct 4-6.

CONFERENCE ON PLASTICS FOAMS, Society of Plastics Engineers, Inc., Buffalo Section. Niagara Falls, N.Y. Oct 5.

2ND INTERNATIONAL CONGRESS ON VACUUM TECHNOLOGY, American Vacuum Society Inc. Washington, D. C. Oct 16-19.

METALLURGICAL SOCIETY, AIME, fall meeting. Detroit. Oct 23-26.

43RD METAL CONGRESS AND EXPOSITION, American Society for Metals. Detroit. Oct 23-27.

AMERICAN SOCIETY OF TOOL AND MANUFACTURING ENGINEERS, semi-annual engineering conference. Toronto. Oct 26-27.

AMERICAN NUCLEAR SOCIETY, 9th hot lab and equipment conference. Chicago. Nov 6.

STEEL FOUNDERS' SOCIETY OF AMERICA, 16th annual technical & operating conference. Cleveland. Nov 13-15.

7TH ANNUAL CONFERENCE ON MAGNETISM AND MAGNETIC MATERIALS, American Institute of Electrical Engineering. Phoenix, Ariz. Nov 13-16.

Reevecote broadens use of popular air switch with stronger— more sensitive diaphragms

T. H. Landgraf, Chief Engineer at The Autogas Company of Bellwood, Illinois, says: "The use of a Reevecote diaphragm allows a wider range of control of all kinds of gases, wider temperature range and provides greater strength."

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Aluminum Island.

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Information wanted on plastics foams

To the Editor:

Your article on foam plastics (M/DE, Mar '61, p 119) refers to the use of urethane foam to form a structure in space. Several months ago we were interested in this and inquired about materials and processes commercially available. Would you be kind enough to refer us to the company whose product you had in mind.

B. J. LEHMAN
Staff Engineer
Lockheed Aircraft Corp.
Van Nuys, Calif.

The information on space-triggered urethane foams was obtained from people working on such a system who did not wish to be quoted directly. As the write-up mentioned, such materials were in the offing, rather than presently available. According to this source, the work has been extremely promising and should produce some practical results within the very near future. As soon as anything more concrete is available, we will certainly plan to publish it.

To the Editor:

We are interested in securing technical data and source contacts on the following foams: 1) polypropylene—open and/or closed cell; 2) polymicrylchloride—a foam-type material used by the Germans several years ago in a radar operation; 3) polyethylene—open cell, in ½ and 1-in. thicknesses; and 4) polyvinylfluoride—open and closed cell, flexible.

LEONARD J. COSTANZA
Los Angeles, Calif.

Information has been sent on polypropylene and polyethylene foams. Frankly, we never heard of either of the other two materials being available as foams.

Government support of research

To the Editor:

I agree completely with Dr. Robert S. Shane's position on government support of materials research (see M/DE, Jan '61, p 166 and Mar '61, p 31). While there is no objection to the universities taking on contract projects for materials research, the time and personnel of the universities can be best employed in teaching principles and fundamentals.

For years I have been prowling around industrial and government laboratories, and I see no signs that the government intends to depend upon the univer-

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sities for materials research. Government contracts continue, and are likely to continue, to go largely to industrial companies.

GEORGE S. BRADY
(Colonel, USA, Ret.)
Industrial Materials Service
Bethesda, Md.

Mandrels for filament wound vessels

To the Editor:

We are interested in materials (and design) for possible use as cylindrical mandrels for the construction of filament wound pressure vessels. After reading your manual on "Filament Wound Reinforced Plastics" (M/DE, Aug '60), I thought you might have some additional information or literature on soluble and collapsible mandrels.

ROBERT A. NIEMAN
Plastics Development Section
Allison Div.
General Motors Corp.
Indianapolis, Ind.

Mandrel materials for filament winding are among the best kept secrets in the industry. The only proprietary soluble mandrel material on the market that we know of is being produced by Rezolin, Inc., Santa Monica, Calif.

Availability of polyvinyl toluene

To the Editor:

In answer to Mr. Carver's question (M/DE, Apr '61) on the availability of polyvinyl toluene, Dow Chemical Co. used to manufacture liquid vinyl toluene monomer and may still be making it. It was tested as early as five years ago as a crosslinking monomer with unsaturated polyester resins. It was substituted for styrene monomer, if I recall correctly, because of its lower volatility and toxicity and possibly better dielectric properties in fabricating radomes or electromagnetic windows.

I have never seen references to polyvinyl toluene (polymer) as such, but . . . our sample can of the monomer eventually polymerized from the liquid to the solid state by itself when the effect of the polymerization inhibitor wore off. The can was cut away and disclosed a hard transparent block. The material, therefore, is probably very similar to styrene and acrylic, which are, of course, available in both monomer and polymer form.

WARREN WALKER
Materials Engineer (Plastics)
Research and Advanced
Development Div.
Avco Mfg. Corp.
Wilmington, Mass.

We checked with Dow and found that they still produce vinyl toluene monomer, but have never produced the polymer.

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Uniform spray, cost-cutting speed . . . to make the most of all the advantages metallizing with molybdenum wire offers, order from Wah Chang.

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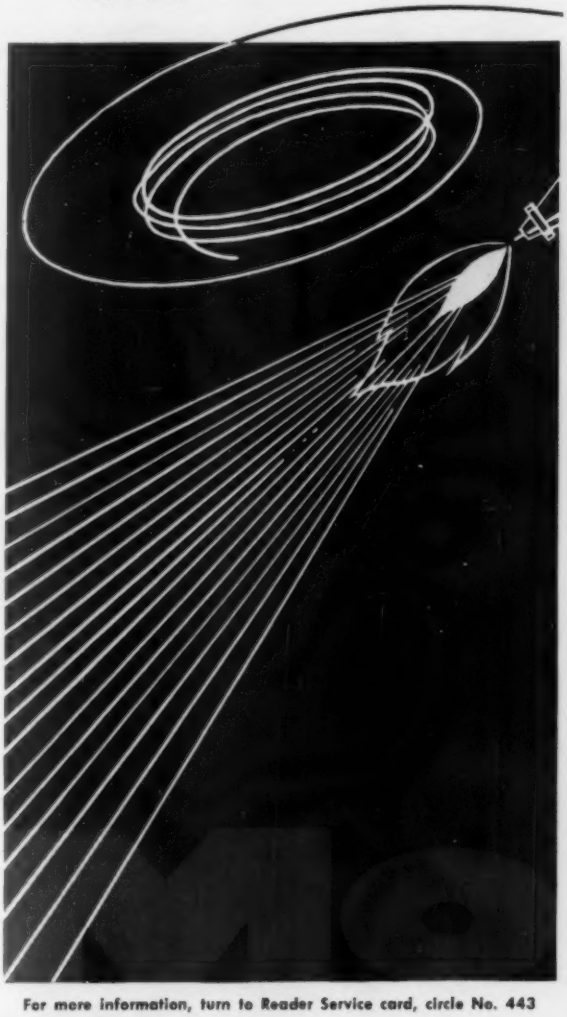

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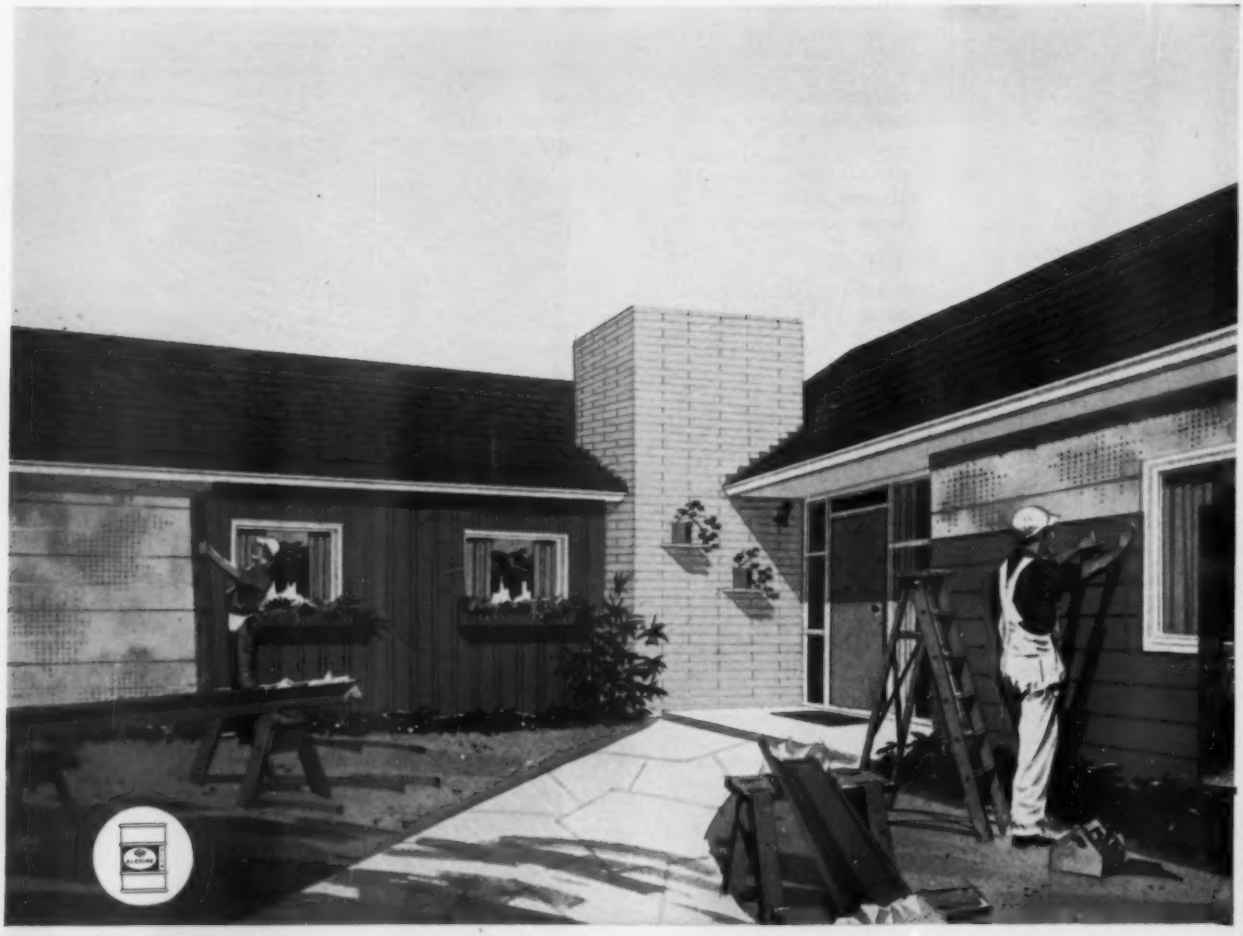
Another finishing first from Amchem!

ALODINE* Chemicals for Spray-Dip Processing Costs in Half Through and Handling at Crown Aluminum!



Crown aluminum siding features beauty, durability and convenience . . . a wide selection of color harmonized paints, year-in, year-out product performance and virtually no maintenance. Amchem Alodine plays a key role in providing the paint system with its outstanding wearing qualities.

Pre-Paint Finishing Slashes Reduced Maintenance, Downtime

Mr. LOUIS HIRSCH, dynamic Crown President says—

"THE INDUSTRY'S FIRST ORIGINAL DESIGN SPRAY-DIP SYSTEM HAS LOWERED THE COST OF SIDING PROCESSING WHILE MAINTAINING HIGH QUALITY AND UNIFORMITY"

Inspired and designed by Amchem in conjunction with Crown engineers and quality control personnel, *the industry's first spray-dip, pre-paint system designed from the ground up,* is providing Crown Aluminum—one of the nation's top three siding producers, with unprecedented savings in processing costs, time and labor.

On several million square feet of aluminum strip treated to date, Crown can point to a 50 percent reduction in overall processing costs through virtual elimination of costly maintenance and downtime. With the addition of this new line, siding production capacity has doubled.

In side-by-side comparisons with an existing all-spray system at Crown's Roxboro (N. C.) plant, the new spray-dip combination has demonstrated outstanding superiority over straight spray—the result of eliminating complicated, time-consuming periodic maintenance associated with spray chamber operation.

Under all of Crown's exacting test standards—salt spray, humidity, infra-red—Alodine quality has remained constant. The proof—not a single paint failure complaint from the field since production started!

If you're considering installation of pre-finishing equipment, or refurbishing your present system—don't make a move till you've investigated Amchem Alodine and spray-dip for coated coil processing. Your nearest Amchem Representative is ready to supply facts and figures on system requirements at your convenience.

* Amchem's registered trademark for its conversion coating chemicals for aluminum.

Crown 5-stage Amchem spray-dip line located on mezzanine level of plant. Overall length of finishing and paint line is 291'6".

Amchem electronic sensing device on stage one cleaner provides automated feed of chemicals.

Amchem Technical Representative conferring with Crown Production Supt. George Hagler (left) on final adjustments to new paint line.

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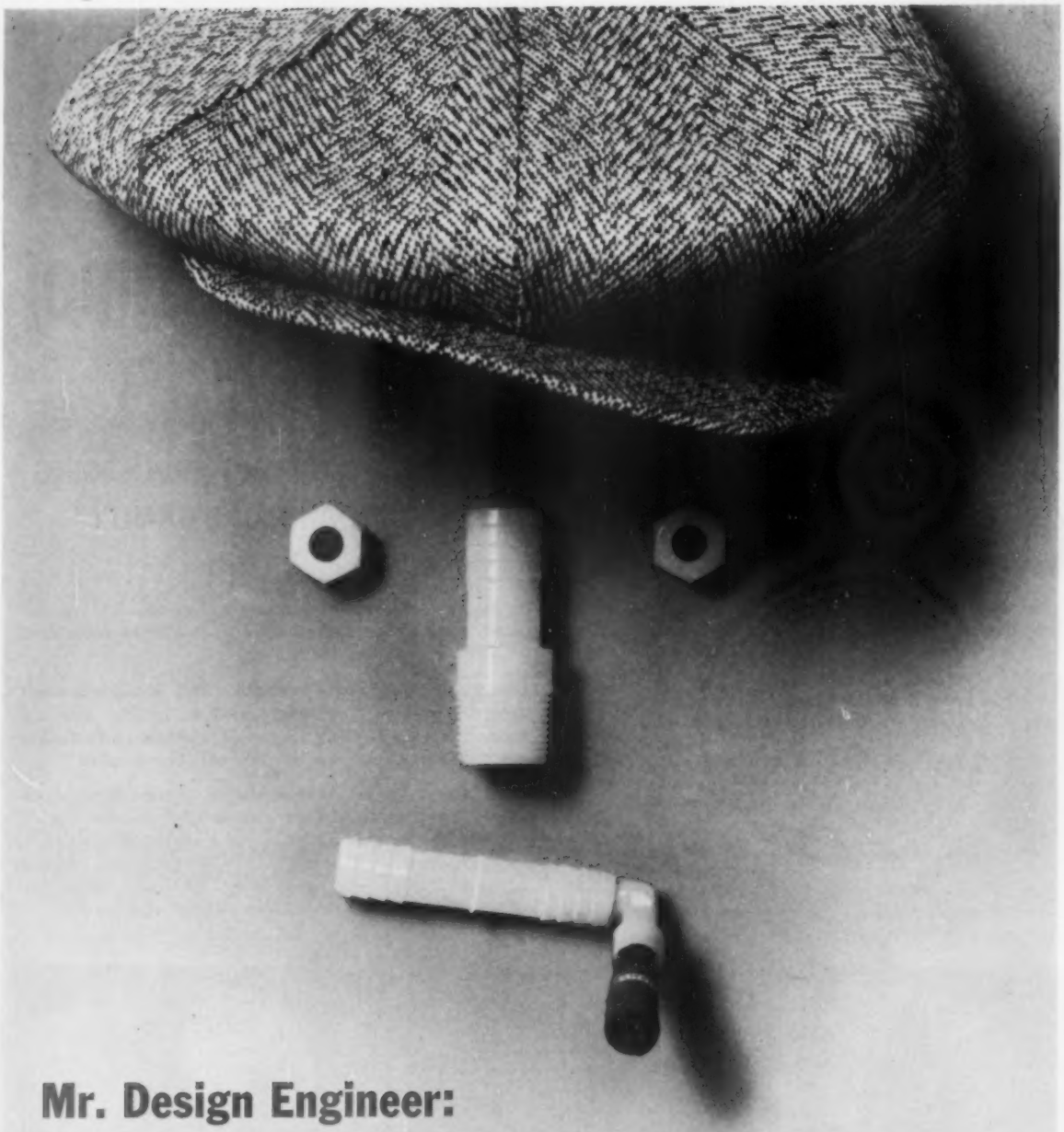
Write for Bulletin 1424C, gives detailed technical specifications on different Alodine chemicals available for pre-treating aluminum.

For more information, turn to Reader Service card, circle No. 422



Mr. Design Engineer:

Here's toughness in all shapes and sizes...

Plaskon® Nylon is always ready when there's a tough job to be done! Rough handling and abuse in both installation and use prove the high impact and tensile strength of pipe fittings molded from Plaskon Nylon. Their corrosion resistance is superior to that of most metals; cost is often much lower.

Now available in sizes up to 4 inches, the insert-type fittings shown above are molded of tough Plaskon Nylon. N.S.F. approved, they are used in jet well installations, industrial piping, air conditioning, and watering systems for livestock, golf courses, lawns, and ice-skating rinks.

Plaskon Nylon injection molding compounds also offer less shrinkage and better dimensional control for precision parts such as gears and bearings. Parts mold easily because Plaskon Nylon doesn't "drool" and has a broader melting range. Call or write for full performance data, and for expert help with any molding problem.

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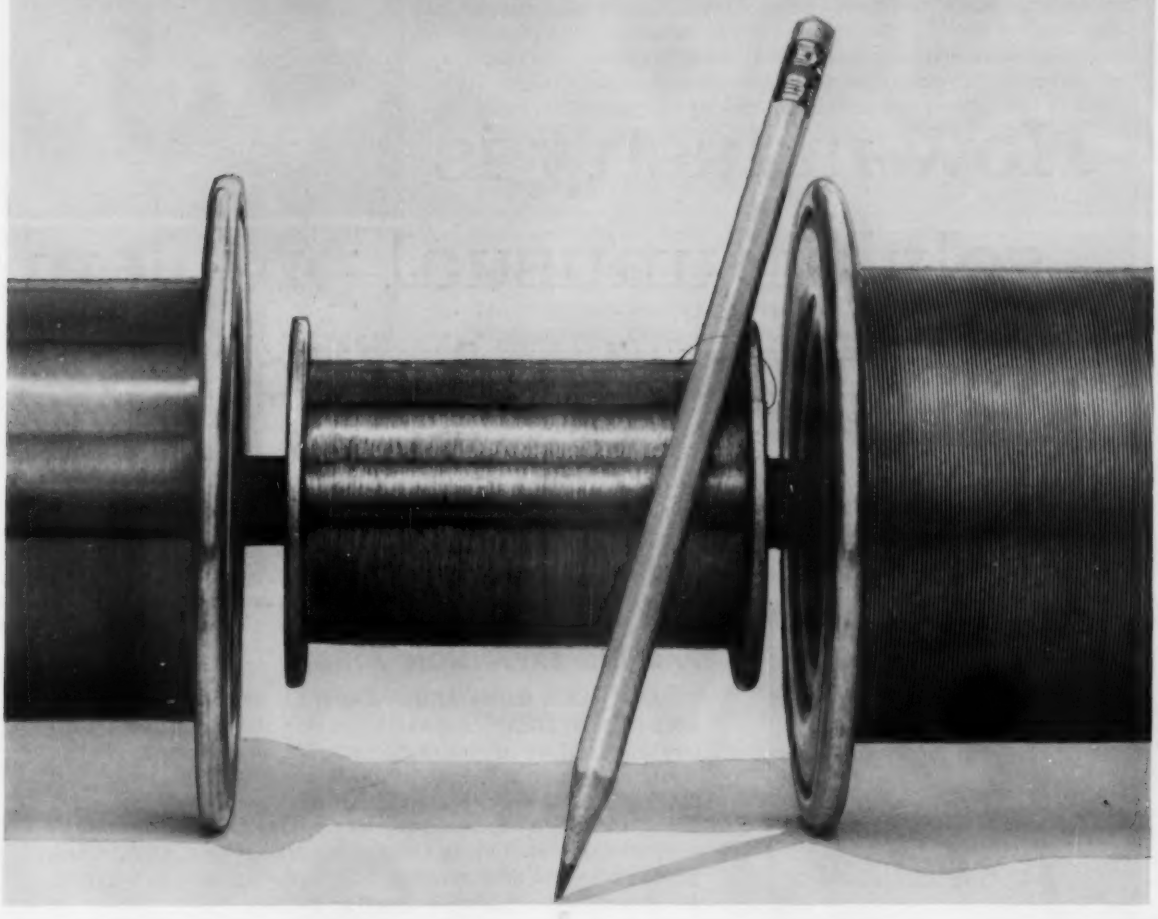

Where to start when you're writing specs

—Let Sylvania give you an unbiased recommendation on wire

When you're designing and specifying materials for special purpose applications, selection of the proper wire can be all-important. Clearly, there are wide variations in corrosion resistance, oxidation resistance, strength and conductivity.

That's why more and more engineers *start* with Sylvania when they specify wire. Of all major manufacturers, only Sylvania makes all three types of bare wire – alloy, clad and plated. Sylvania makes them in a full range of sizes, too—.002″ to .250″. Each and every one retains optimum characteristics up to recommended operating temperatures.

With such a complete line, you can be sure that a Sylvania recommendation is unbiased. It's based on *your* needs—*not* restricted by a limited line. Full details—for future use or help on a present project—are yours at Sylvania Electric Products Inc., Parts Division, Warren, Pennsylvania. Call or write.

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Report from Carborundum:

How industry is solving unusual problems with unusual refractories

PACKING EXPANSION JOINTS:

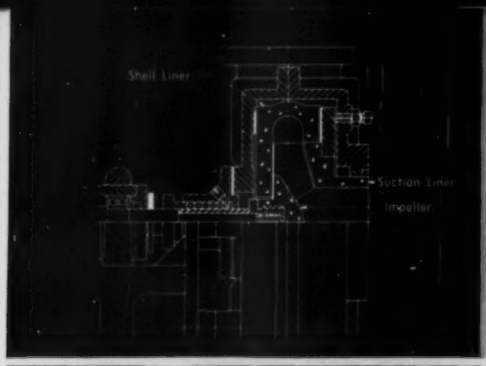
CERAMIC FIBER WITHSTANDS 2300°F; EASILY PACKED; OBTAINABLE IN MANY FORMS. FIBERFRAX® ceramic fiber extends the temperature ceiling of fibrous insulating materials; opens new application areas. In rope or bulk form, it makes an excellent expansion-joint packing for refractory furnace walls. It is light in weight, highly resilient, does not shrink, is impervious to heat shock, and is inert to most furnace atmospheres. Various forms of FIBERFRAX — e.g. cloth, board, paper etc. — also offer advantages for gasketing, sealing, wrapping, lining, encapsulating, blanketing and jacketing.

ZINC ORE REDUCTION IN VERTICAL RETORT:

RUGGED REFRACTORY WALLS CONDUCT HEAT FAST, STAY GAS TIGHT. Five million Btu's must be transferred through refractory walls such as shown at left for every ton of zinc produced. High heat conductivity — 11 times that of firebrick — is provided by CARBOFRAX® silicon carbide retort walls. Internal temperatures reach 2000°F. Other important refractory properties: great physical strength at high temperatures, chemical inertness, and unequalled abrasion and erosion resistance. Low permeability is also important because gas-vapor mixtures produced in the retort must be contained.

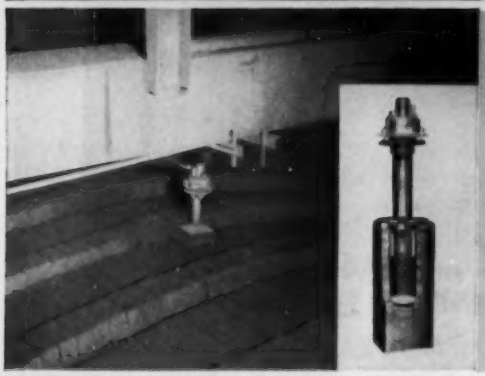
SPRAY NOZZLE FOR CORROSIVE SERVICE:

REFRACTORY REPLACES METALS—RESISTS HIGH TEMPERATURES, CORROSION, THERMAL SHOCK. The nozzle illustrated sprays a 15% solution of SO_2 in water at 150°F into a chamber operating at over 1700°F. Conditions involve severe thermal shock and corrosion. Previously used metal nozzles often lasted less than two months. Nozzles made of Carborundum's silicon carbide have shown no signs of failure after **five years** of service — another example of how these versatile refractories can take unusual forms to meet highly specialized problems.



PUMPING ABRASIVE SLURRIES:

REFRACTORY PARTS FOR PUMP RESIST WEAR, OUTLAST HARDEST METAL ALLOYS. Development of REFRAX®, a silicon-nitride-bonded silicon carbide, makes it possible to use refractories in many applications usually requiring metals. It can be formed with high dimensional accuracy as well as a high finish. Examples of use are impellers and shell liners in "Lightning" sand and gravel pumps made by Kansas City Hay Press Co. Comparative performance during a six months' test pumping 150 GPM of water with 20% silica sand against a 70-foot head has shown that REFRAX parts give more than **five times** the life of duplicate parts made of nickel chrome alloy.



MAKING 200 TONS OF STEEL BEHAVE:

TARGET BLOCK HELPS KEEP FURNACE TEMPERATURE AT MAXIMUM PRODUCTION LEVEL. The temperature detector shown in the open hearth roof at left is mounted in a hollow silicon carbide block. The detector is focused on a target disc made of another one of Carborundum's refractories — REFRAX refractory. Radiated heat from the disc provides a constant check on roof temperature . . . assures maximum production without danger of "losing" the roof. These two refractories provide the necessary properties of high heat conductivity, resistance to high temperatures and furnace gases and exceptional hot strength. Device is manufactured by Leeds & Northrup Co.

FIRING ELECTRICAL PORCELAINS:

SILICON CARBIDE KILN FURNITURE SIMPLIFIES CAR SETTINGS, PROTECTS WARE; IMPROVES HEAT CIRCULATION. Kiln car at left is loaded with electrical insulators supported by CARBOFRAX silicon carbide tile, posts and girders. Setting enables car to carry maximum load; may be rearranged as needed to suit different sizes of ware. CARBOFRAX furniture possesses high hot strength, resists deformation, reduces breakage losses — in trip after trip through the kiln. Furniture is also designed to permit uniform circulaton of heat through and around car for best ware firing conditions.

SINTER-PLANT DUST COLLECTOR:

REFRACTORY LINING LASTS YEARS IN SERVICE INVOLVING HIGH-VELOCITY GAS AND ABRASIVE PARTICLES. Superior resistance to entrained abrasive particles is shown by a lining made of a Carborundum-made refractory in this primary dust collector. Cone lined with Carborundum's material has handled more than 2,500,000 lbs of abrasive sinter dust in **seven years.** Ordinary brick in other parts of the same collector has worn back to the shell in only 5 months. Other wear-resistant applications for Carborundum's refractories are in duct linings, blast furnace downcomers, hydro cyclones, chutes, bins, feeder tables, gas scrubbers, nozzles and other related applications.

Want help on your problems?

Carborundum engineers will be glad to recommend refractories to answer your specific needs. For information, contact Dept. MD-61 Refractories Division, Carborundum Co., Perth Amboy, N. J. Descriptive brochures available on request. Please specify the area or areas of particular interest to you.

for engineered refractories . . . count on

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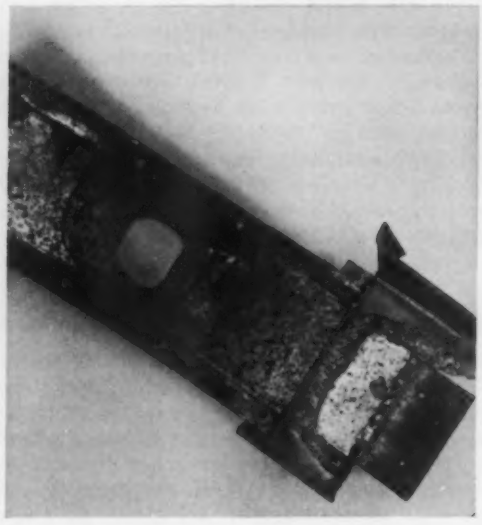

175° F. sand, being blown to storage, regularly wore through special abrasion-resistant alloy steel wear plates at duct elbows in only 2 months.

Abrasive sand finally gnawed through ADIPRENE® urethane rubber liner in elbows – but it took 6 months.

Foundry finds ADIPRENE® outwears steel 3 to 1

This interesting application shows dramatically how tough ADIPRENE urethane rubber really is. And designers are finding that this outstanding abrasion resistance . . . plus excellent load bearing capacity and low temperature resistance . . . is the solution to many design problems.

For example, industrial wheels made of ADIPRENE are outlasting those made of ordinary rubber 5 to 1. A leading auto manufacturer is using ADIPRENE for longer lasting ball joint seals. Manufacturers in both civilian and defense industries use ADIPRENE for impact, shock and abrasion resistant mounts, bumpers, bushings, suspension straps. A metalworking company is employing ADIPRENE as a female stamping die . . . finds that it survives 50,000 impacts as compared to only 400 for ordinary rubber. From "potting" to pulleys . . . from shoe heels to shock resistant grinding wheels . . . ADIPRENE's unique set of properties can help you design better, longer lasting new products. For more information about ADIPRENE write E. I. du Pont de Nemours & Co. (Inc.), Elastomer Chemicals Dept. MDE-6, Wilmington 98, Delaware.

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McLOUTH STAINLESS STEEL—the CLEAN metal for kitchens and food handling.

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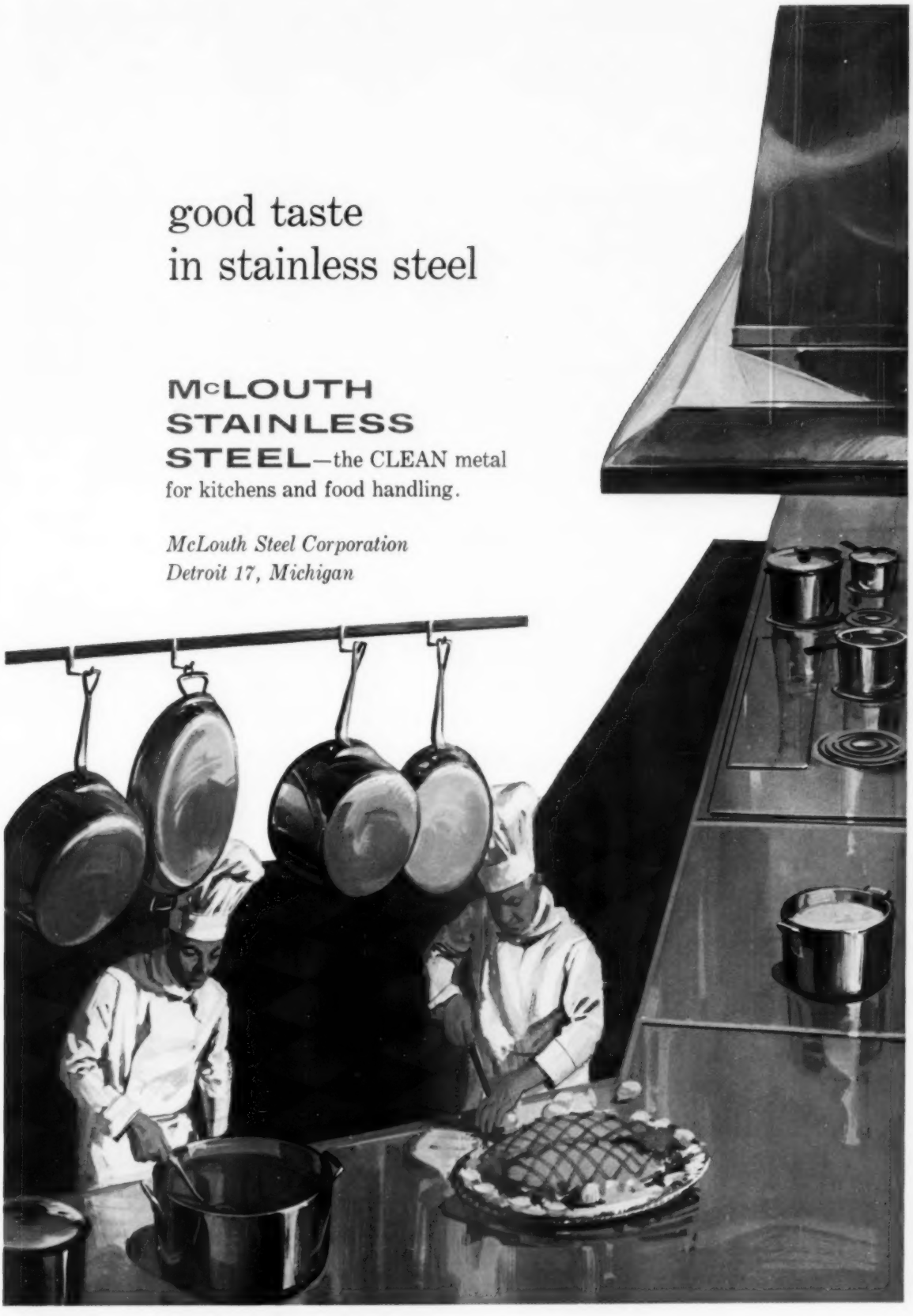

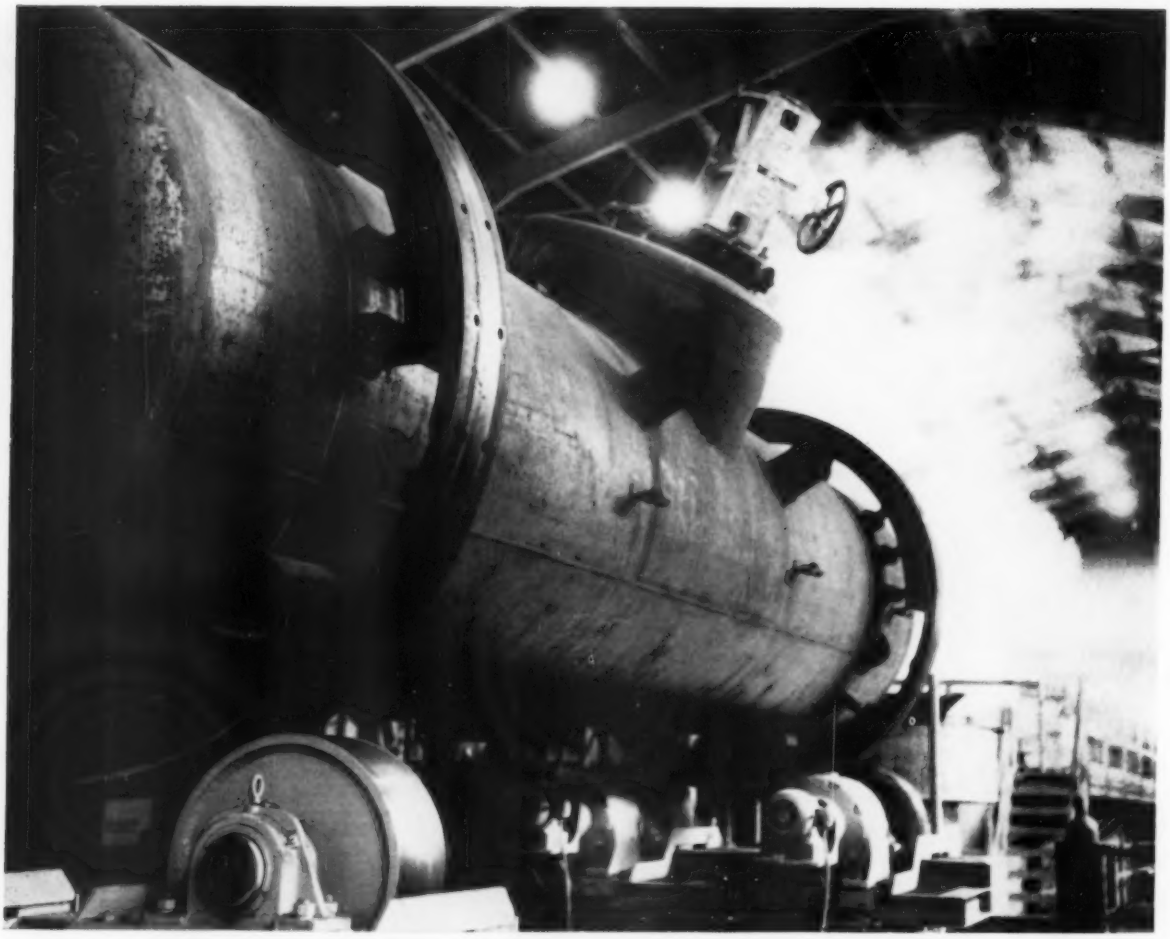

The specialists at General American's Kanigen plant in Sharon, Pennsylvania can deposit an even coating of hard nickel alloy on most ferrous metals in common use. Regardless of how high, wide or heavy the object is, if you can get it to Sharon, we can plate its interior.

Before General American developed Kanigen coating, it was next to impossible to deposit an even nickel plating over very large surfaces or on many complex shapes. Since Kanigen nickel plating is purely a chemical process involving no electric current, it works equally well on simple or complex shapes and on small or large surfaces. Thickness uniformity of the coating is independent of part complexity or size.

Only General American and its authorized licensees around the world can show you how Kanigen coating may improve your product. The Kanigen process is protected by more than 30 separate patents. For detailed technical literature, write for bulletin No. 561.

IF YOU CAN SHIP IT

WE CAN PLATE IT!

NO MATTER WHAT THE SIZE OR SHAPE OF YOUR PRODUCT, IT CAN BE COATED BETTER WITH KANIGEN® NICKEL ALLOY

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for quality in appearance and performance

Plexiglas...Implex

Why are there so many parts molded of IMPLEX®, the high-impact acrylic, and PLEXIGLAS® acrylic plastic on the 1961 Ramblers? Here are the reasons.

IMPLEX is used for metallized armrest supports because of its superior *toughness* . . . for air conditioner housings and grilles because of its excellent *appearance*, its *strength* and good *moldability* in thin sections . . . for radio, window crank and gear shift knobs because of its *dimensional stability* and *stain resistance*.

PLEXIGLAS is used for tail light, back-up and parking light lenses because of its outstanding *optical properties* and *weather resistance* . . . for the speedometer dial because it calls for *edge-lighting* . . . for medallions and other ornaments because the *crystal clarity* of PLEXIGLAS gives depth and sparkle to back-surface decorations.

The properties of these Rohm & Haas molding materials may well benefit a part on which you are working. Our design staff will be pleased to help you use PLEXIGLAS and IMPLEX to your advantage.

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How to use Clad-Rex vinyl-clad metal in the design and engineering of hospital furniture and other products

Vinyl-Clad metal used in patient room furniture by American Seating

The sheet metal nature of Clad-Rex vinyl-clad metal would seem to indicate generally how it can be used. However, the unusual characteristics added by the vinyl coating itself make the areas of usage much broader than might be expected. So as not to overlook possible applications within your product line, consider Clad-Rex as a basic material. Measure each of its advantages against the individual parts and subassemblies of your products as well as the whole enclosure. In this manner your manufacturing methods and costs, your sales appeal, and product profit can be best helped.

The sales appeal of Clad-Rex vinyl-clad metal

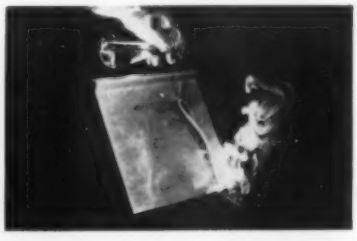
The vinyl surface of Clad-Rex is, in fact, a finish. It is available in a broad range of colors and embossed textures. Actually, Clad-Rex provides an almost unlimited variety of stock and custom multi-color patterns. Special prints in register can be provided also. The stock line, bleached walnut decor used by American Seating gives the feel and rich warmth of fine wood.

The abrasion resistance of Clad-Rex vinyl-clad metal

The vinyl surface of Clad-Rex, being a poly-vinyl chloride film, offers great resistance to abrasion. This wearability would include scuffing and scraping. Texturing effectively hides even deep cuts in the vinyl surface. This resistance to abrasion enables American Seating to capitalize on fine finish without extraordinary care in handling during manufacturing. Matter of fact, rejects common to highly finished products are greatly reduced with vinyl-clad metals.

The corrosion resistance of Clad-Rex vinyl-clad metal

Having all the advantages of poly-vinyl chloride, the surface of Clad-Rex vinyl-clad metal protects against acids, alkalis and other corrosive chemicals. It is free of pin holes. As a result, it offers unusual dielectric properties as well.



The tops of the "Bedside Susan" Cabinet and "Overbed" Butler in the American Seating group are sanitary white, non-staining Clad-Rex.

The fabrication of Clad-Rex vinyl-clad metal

American Seating methods for fabricating Clad-Rex vinyl-clad metal are much like they used for bare sheet metal. Finishing, of course, is not needed. Press and brake forming, crimping, etc., are all practical.

Most important to any remarks about fabrication—although Clad-Rex is obviously different from bare metal, the unusual quality of the vinyl-to-metal bond tends to minimize the difference. As a result, American Seating fabricates within their own facilities without complex or unusual techniques or tooling.

All conventional, mechanical methods of fastening are commonly used. However, although vinyl-clad metal parts can be assembled with stud and projection resistance welding, some limitations in spot and seam welding do exist. Until the present research for a solution is completed, other conventional methods of joining must be used.

A source of engineering service

Take full advantage of the engineering and research facilities of Clad-Rex. Call or write for Report 6101, "How to Use Vinyl-Clad Metal in the Design and Engineering of Commercial Furniture". *Simoniz Industrial Products, 11512 West King Street, Franklin Park, Illinois (Phone Gladstone 1-2323).*

Clad-Rex Vinyl-Clad Metal is a product of

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Ameripol Rubber helps ball maker bounce back into competition

Intensified competition in selling sponge rubber balls inspired a thorough cost study by Barr Rubber Products Company. To help make it, they called in a Goodrich-Gulf sales engineer. A switch from natural rubber to an Ameripol synthetic rubber polymer really produced results. Barr was able to cut its raw material costs substantially. Quality of the end product is maintained at the same high level, and processibility improved. If you make or use rubber products, check Goodrich-Gulf. We produce the broadest range of synthetic rubber polymers, and offer complete technical service that can help you make improvements. Contact Goodrich-Gulf Chemicals, Inc., 1717 East 9th Street, Cleveland 14, Ohio.

Ameripol
THE PREFERRED RUBBER

Goodrich-Gulf Chemicals, Inc.
WORLD'S LARGEST SOURCE OF SYNTHETIC RUBBER

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Said Isaac Newton:

"Every particle of matter attracts every other particle with a force directly proportional to the product of their masses and inversely proportional to the square of the distances between them."

Until recently, the thrust which propelled rocket vehicles into their coast stage, prior to orbiting, was provided by booster stages. The fuel carried by the satellite stage was used only to inject itself into orbit.

Now, however, a scientist at Lockheed Missiles and Space Division has evolved a Dual Burning Propulsion System which allows higher orbits and heavier payloads. With this system, the satellite vehicle fires immediately after the last booster stage burns out, thus augmenting the begin-coast speed. Later the satellite stage is re-started to provide orbit injection.

An even more recent development by Lockheed is a triple-burning satellite stage. This will permit a precise 24-hour equatorial orbit, even though the vehicle is launched a considerable distance from the equator.

These principles have made possible the early development of the MIDAS satellite. Moreover, they substantially increase the altitude and payload of the DISCOVERER series. Lockheed, Systems Manager for these programs and for the POLARIS FBM, is pursuing even more advanced research and development projects. As a result, there are ever-widening opportunities for creative engineers and scientists in their chosen fields.

Why not investigate future possibilities at Lockheed? Write Research and Development Staff, Dept. M-15D, 962 West El Camino Real, Sunnyvale, Calif. U.S. citizenship or existing Department of Defense industrial security clearance required.

All qualified applicants will receive consideration for employment without regard to race, creed, color or national origin.

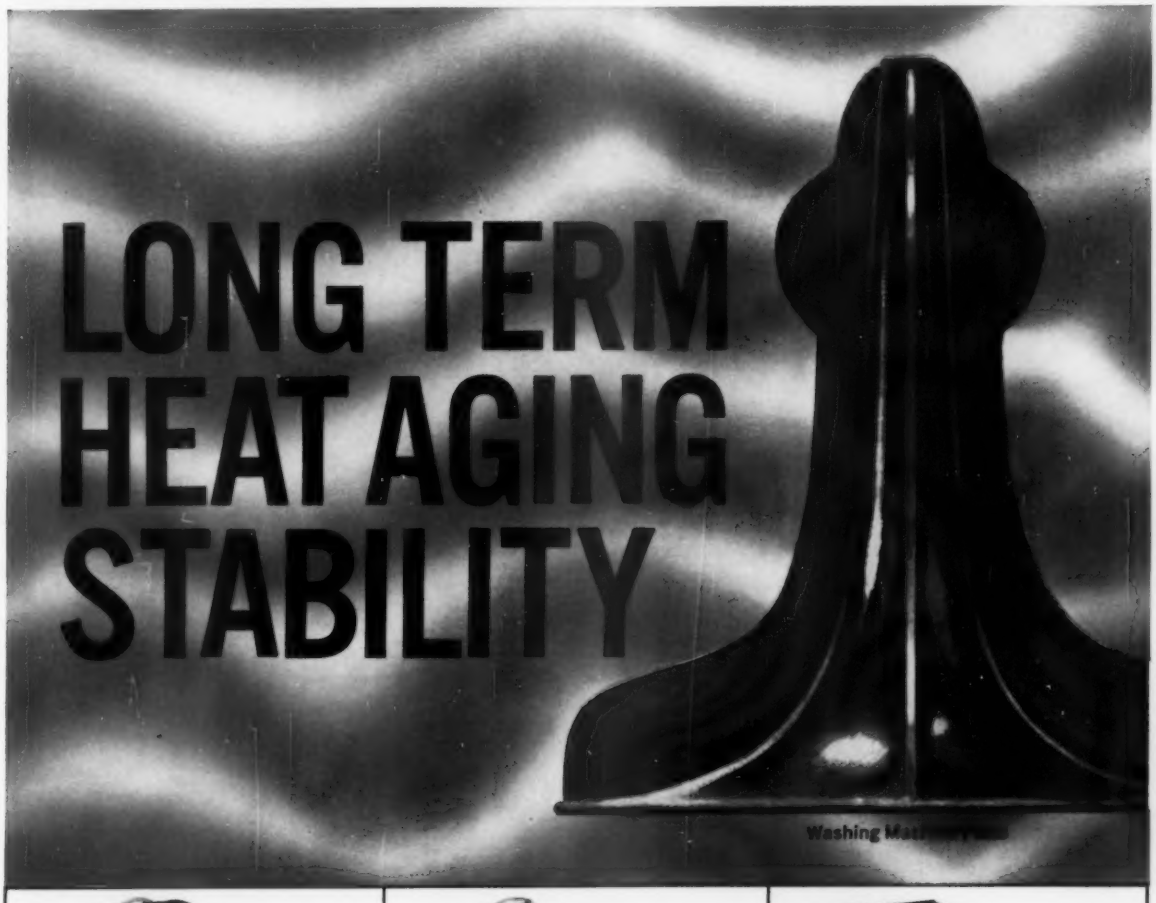
Lockheed / **MISSILES AND SPACE DIVISION**

Systems Manager for the Navy POLARIS FBM and the Air Force AGENA Satellite in the DISCOVERER and MIDAS Programs

SUNNYVALE, PALO ALTO, VAN NUYS, SANTA CRUZ, SANTA MARIA, CALIFORNIA • CAPE CANAVERAL, FLORIDA • HAWAII

What's News in Plastics...

LONG TERM HEAT AGING STABILITY



TV Backings

Vaporizers

Radio Cabinets

Yours with new Escon® 125 molding grade polypropylene!

Household appliances, radio cabinets and TV backings take full advantage of the remarkable properties of Escon 125 polypropylene. This outstanding new grade is designed to maximize performance for long periods at high temperatures. Exceptional performance is achieved through a special LTHA (Long Term Heat Aging) stabilization system developed by Enjay research affiliates.

Escon 125 offers oxidative stability that, in carefully conducted laboratory tests against other commercially available grades of polypropylene designed for this type of service, outperformed all others tested. Specimens of Escon 125 withstood almost three months of oxidative aging at 300°F; specimens exposed to 250°F have shown no signs of failure after seven months.

Melt index is 5.5 at 230°C. No changes are required in equipment, processing conditions or coloring techniques from those used with general purpose molding grades. For test samples and typical properties of new Escon 125, write to Enjay, 15 West 51st Street, New York 19, New York.

EXCITING NEW PRODUCTS THROUGH PETRO-CHEMISTRY

ENJAY CHEMICAL COMPANY

A DIVISION OF HUMBLE OIL & REFINING COMPANY

ENJAY PLASTICS

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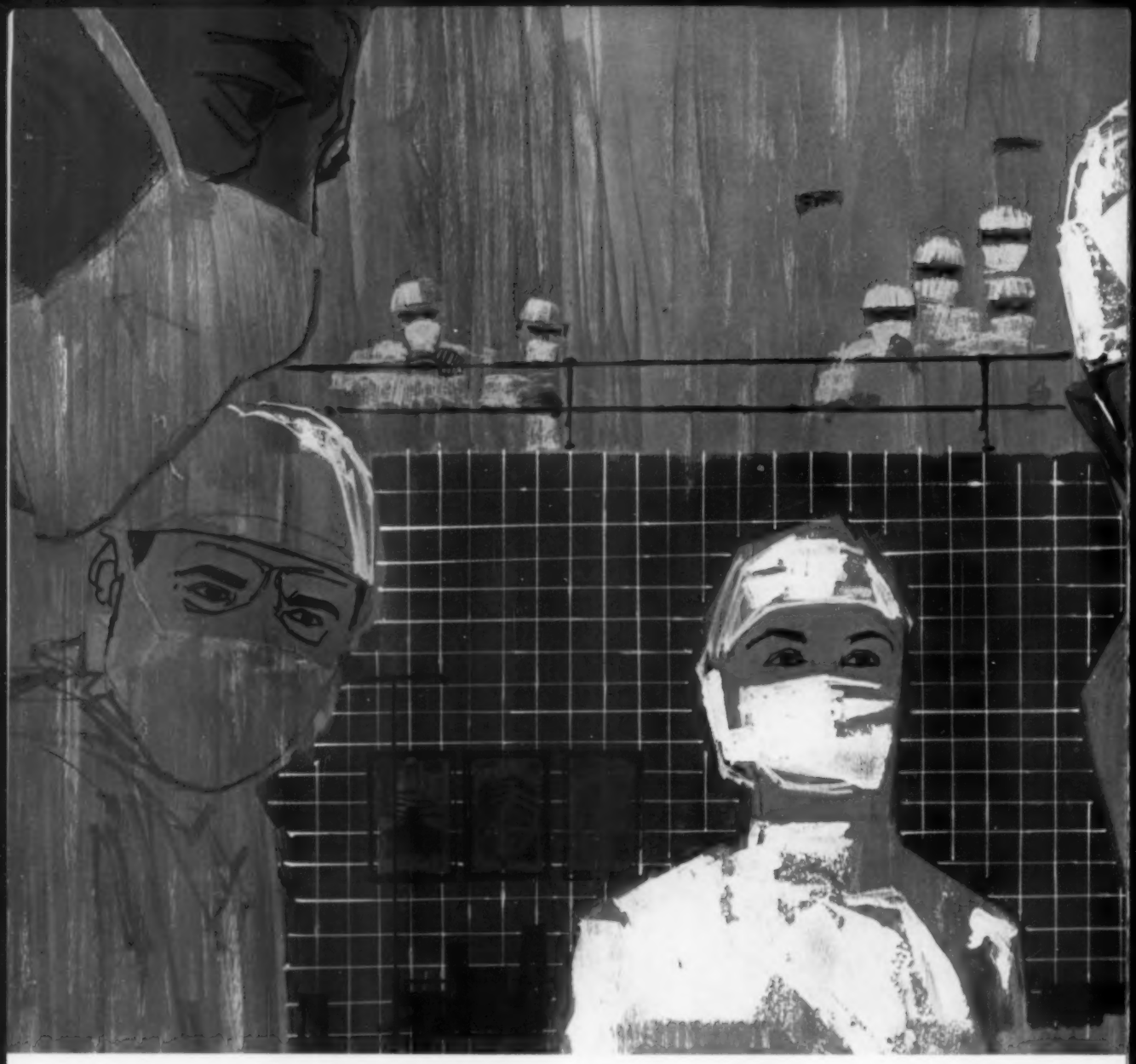


NS SPECIAL WIRE TRANSMITS

Doctors are saving more lives today in heart surgery cases through the transmission of carefully timed electrical pulses into the heart. Many patients suffering from lost heartbeat due to surgery or other causes have been restored to active life through such heart stimulation.

A LEADING MEDICAL INSTRUMENT COMPANY developed a pocket-size electronic package to generate the electrical impulse, which is transmitted to the heart through the jugular vein by a tiny stainless steel braided wire.

In their search for the right conductor to carry the electric pulses to the heart, researchers came to National-Standard for help in developing a wire flexible enough to follow the intricate path of the circulatory system, while, at the same time, soft enough to avoid damaging the blood vessels or the heart itself. In addition, the wire had to be very thin, strong enough to withstand the constant flexing of the heart, and with just the proper electrical characteristics.

NATIONAL-STANDARD ENGINEERS developed a braid of 16 wires, each .0036″ diameter, or about the thickness of human hair. Using type 302 stainless

SPARK OF LIFE

steel wire, NS engineers produced a braided wire with high tensile strength, good resistance to fracture, good conductivity and flexibility just right for the delicate application.

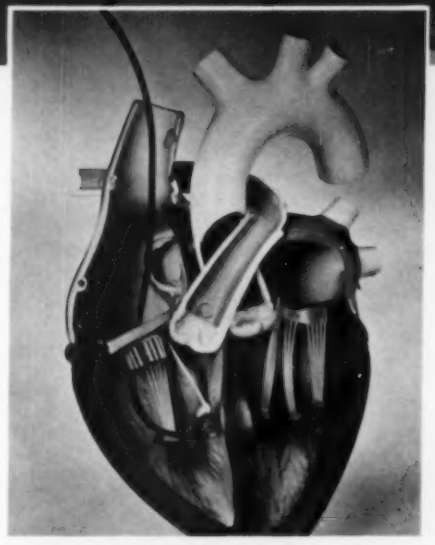
EXPERIENCED ENGINEERING HELP of this kind, for jobs requiring high-quality wire, to meet special or unique applications, is available to you from National-Standard. Write for additional information to National-Standard Company, Niles, Michigan.

NS NATIONAL STANDARD COMPANY

Manufacturer of Specialty Wire and Metal Products

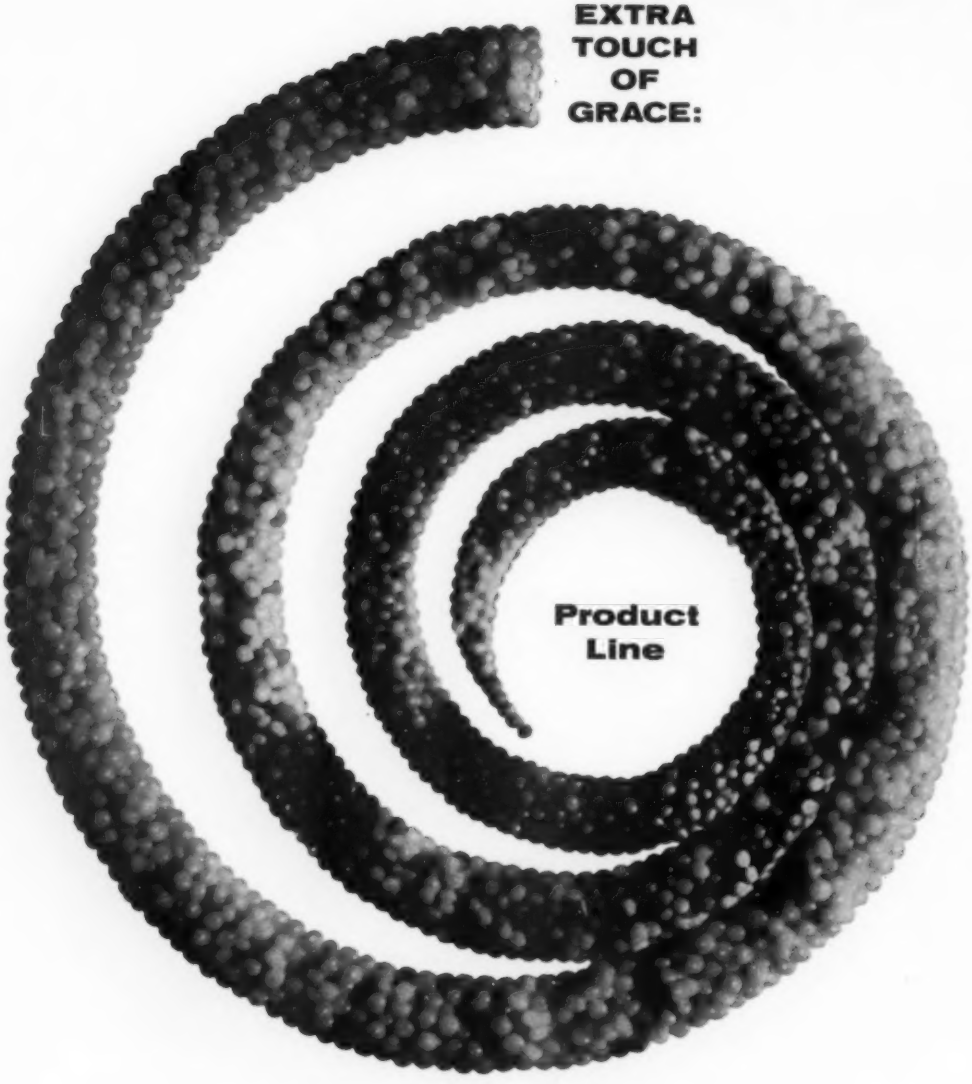
NATIONAL-STANDARD COMPANY

Niles, Michigan



NS SPECIAL WIRE transmits spark of life from transistorized, battery-powered package, through jugular vein, to the heart. Carefully timed electrical pulses train tired hearts to beat normally again.

THAT EXTRA TOUCH OF GRACE:



A full line of modern thermoplastics is one of the ten major services offered by the Grace Service Plan. You get expert assistance in selecting from a range of versatile materials: high density polyethylene, low and medium density polyethylene, polystyrenes, and special compounds such as flame retardant and electrical insulating materials. And now we offer you Moplen* polypropylenes to help you decide on just the right plastic to do the right job. It costs no more to call for that extra touch of Grace.

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Galvanized sheet has improved paintability	180	620
PLASTICS & RUBBER		
Plastics laminates for electronic parts	165	610 to 612
Flexible polyethylene competes with vinyls	172	615
Vinyl surfacing mat	176	618
Clear silicone for encapsulating, potting	178	619
Rubber liners protect against abrasion	182	621 & 622
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Beryllia heat sinks	174	617
Clean lubricating grease	186	632
Subminiature ceramic parts	186	633
FINISHES, COATINGS		
Neoprene-base paint for outdoor uses	168	613
New organic coating resists acids, mortar	184	623
Bright dip for cadmium	186	634
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Physical Properties and tests	676
Designing with Metal Powder Parts..	675
Organic Coatings for Metal Products..	674
Guide to Plastics Selection.....	673
How to Select a Stainless Steel.....	672
Sheet Formed Plastics Parts.....	671
Sleeve Bearing Materials	670
Designing Metal Stampings	669
Paper as an Engineering Material....	668
Porcelain Enamels Ceramic Coatings..	667
Designing with Heat Treated Steels...	666
New Developments in Ceramics.....	665
Thermal Insulation Materials.....	664

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Suppliers' Literature
Books, p 51
Reports, p 52

Suppliers' New Bulletins

Polyester Resins. American Cyanamid Co., Plastics & Resins Div., 10 pp, illus. Chemistry, classification, characteristics, and hints on the selection of polyester resins. **1**

Properties of Ceramics. American Lava Corp., Steatite Div., illus., No. 611. Chart lists physical, mechanical, and electrical properties of steatite, forsterite, zircon, cordierite, alumina, and other ceramic materials. **2**

Copper-Base Alloys. Ampco Metal, Inc., 16 pp, illus., No. G-60. Chemical compositions, physical properties, and typical applications of a series of wear and corrosion resistant copper-base alloys. Includes a description of services and facilities available for the production of sand, centrifugal, and shell mold castings; extrusions; machined parts; and fabrications and finished products. **3**

Vacuum Metallizing. Bee Chemical Co., 4 pp, illus. Chart lists surface and property desired, recommended metallizing systems, method of coating and thinning, and typical properties. **4**

Ultrasonic Cleaning. Branson Instruments, Inc., 14 pp, No. S-700. Physical properties, suggested applications, working temperatures, procedures, and other information on several chemicals used in ultrasonic cleaning. **5**

Magnesium Products. Brooks & Perkins, Inc., 16 pp, illus., Feb. '61. Information on services and facilities available for the production of magnesium, titanium, aluminum, and boral products. Includes a series of case histories describing various parts currently being produced for the aerospace industry. **6**

High Temperature Materials. Carborundum Co., Advanced Materials Technology, 8 pp, illus. Advantages, characteristics, physical and mechanical properties, corrosion resistance, typical applications, and other information on silicone carbide, ceramic fibers, boron nitride, zirconium and zirconium alloys, hafnium, ceramics, and other high temperature materials. **7**

Machining Stainless Steels. Carpenter Steel Co. Slide chart gives precise data on turning, drilling, tapping, threading, milling, and reaming stainless steels. Includes relative workability and information on such operations as blanking, deep drawing, stamping, forging, heading, roll threading, welding, etc. **8**

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TFE, Reinforced TFE. Dixon Corp., Plastics Div., 4 pp, illus., No. 9572. Compares electrical, physical, mechanical, and chemical properties of reinforced and conventional TFE fluorocarbon plastics. Includes information on basic shapes and typical fabricated parts. **12**

Floating Structures. Dow Chemical Co., Plastics Sales Dept., 24 pp, illus., No. 32-B (NN). Advantages, limitations, sizes, properties, design information, and typical applications of floating structures made with polystyrene foams. **13**

Porcelain Enameled Parts. Erie Ceramic Arts Co., 4 pp, illus., No. 1g/er. Physical, chemical, thermal, electrical, and surface properties; advantages; and typical applications of small porcelain enameled parts. Includes a description of services and facilities available. **14**

Aluminum Selector Chart. Fairmont Aluminum Co., 6 pp. Strength, thermal and electrical conductivity, density, specific gravity, melting range, weight, tolerances, fabrication characteristics, available finishes, hardening properties, embossing designations, and typical uses for ten most used aluminum alloys. **15**

Friction Materials. Firestone Tire & Rubber Co., World Bestos Div., 4 pp, illus., No. 1051. Size limits, tolerances, material descriptions, tensile strength, coefficient of friction, recommended service, and other information on parts and materials for brakes, clutches, automatic transmissions, and vibration dampers. **16**

TFE Products. Fluorocarbon Co., 4 pp. Information on services and facilities available for the production of TFE and Kel-F fluorocarbon products. **17**

Diallyl Phthalate Varnishes. Food Machinery & Chemical Corp., Chemicals & Plastics Div., Dapon Dept., 8 pp, illus., No. 32. Information on the formulation and use of insulating varnishes based on diallyl phthalate resins. Includes information on properties and uses of diallyl phthalate for coating, sealing, dip encapsulation, and laminating applications. **18**

Lithium Compounds. Foote Mineral Co., 6 pp, No. 108. Specifications, chemical analyses, properties, present and suggested uses, and other information on several lithium compounds. **19**

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Silicone Potting Compounds. General Electric Co., Silicone Products Dept., 4 pp, illus., No. CDS-280. Advantages, characteristics, properties, typical applications, and instruction on the use of a clear silicone potting compound. **21**

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TECHNICAL LITERATURE

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Powder Metallurgy Parts. Wickes Corp., U. S. Graphite Co. Div., 8 pp, illus., No. 21. General description of powder metallurgy process, and specific discussions of bronze metal powder bearings, including properties, running clearances, and methods of assembly. **43**

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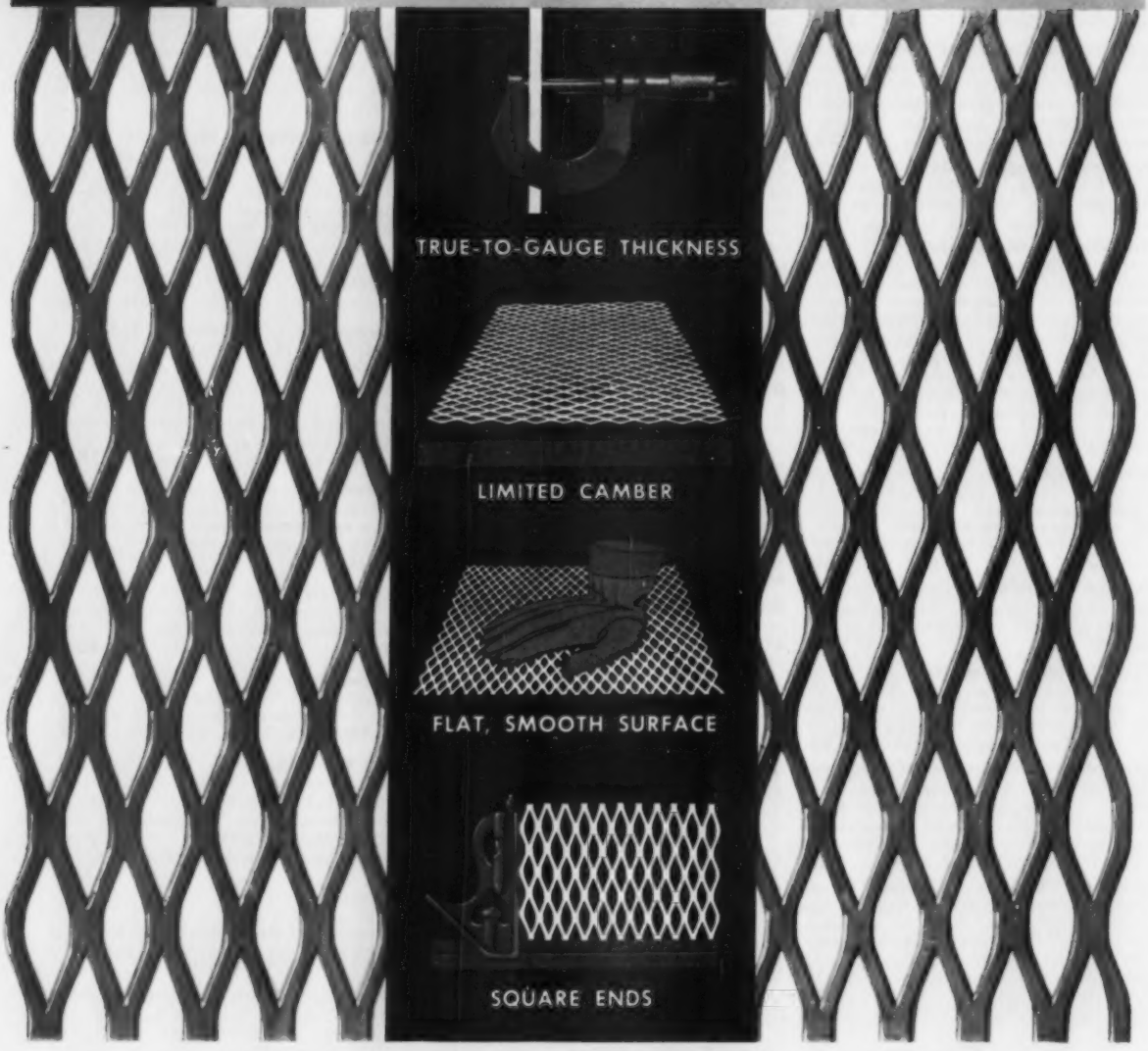

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Wheeling Long Terne is available in widths to 48". It is normally supplied with either commercial or special terne coatings.

TECHNICAL LITERATURE

(cont'd from p 49)

Books

Introduction to Ceramics. *W. D. Kingery. John Wiley & Sons, Inc., New York. 1960. Cloth, 6 by 9 in., 781 pp. Price $15*

Reviewed by L. H. Van Vlack*

This book is a most welcome addition to the ceramic literature. Professor Kingery, using a solid-state chemistry and physics approach, has unified the sciences as they pertain to ceramic materials and has prepared the most thorough and authoritative compilation of knowledge in this field.

The author is well qualified in the area of ceramics. His activities have included basic research, authorship of several dozen scientific papers, organization of technical symposia, and editorship of several books. He is, in fact, considered to be the country's scientific leader in the field of ceramics.

Introduction to Ceramics is organized into five sections. The first two (which present introductory information and descriptions of ceramic processes) provide the stage for the last three sections, which contain the meat of the book. These sections are: Characteristics of Ceramic Solids, Development of Microstructure in Ceramics, and Properties of Ceramics.

Atomic relationships

Ceramic solids are discussed from the standpoint of their atomic relationships. This is a very logical approach because many of the properties of ceramic materials depend upon the interaction of neighboring atoms. Dr. Kingery presents separate discussions of crystal structure, noncrystallinity, structural imperfections, surfaces and interfaces, and diffusion. However, the discussions are correlated to maintain the unity of principles.

Microstructures

Next, ceramic microstructures are introduced through phase equilibrium diagrams; following this are discussions of solid-state reactions, nonequilibrium phases, and the effects of thermal treatment (such as sintering and vitrification). Specific attention is given to the microstructure of such materials as refractories, structural products, glasses, electrical ceramics, and other related groups.

Properties

The final two-fifths of the book is concerned with the properties of ceramics. This part of the publication (to which the author's personal contribution is the greatest) will prove to be the most lasting contribution of the book. Heretofore, the bases for analyzing properties have been dispersed among a variety of publications. Now the physical-chemical principles which govern the various properties have been summarized in one source. Specific attention is given to thermal, optical, deformation, strength, conductivity, and dielectric and magnetic properties.

Two additional statements should be made for the potential reader. First, the book is primarily a science book; as such, major attention is given to the analysis of materials and their properties. And although the book gives excellent coverage to applications, no attention is given to the utilization synthesis for design considerations. This may be disappointing to some design engineers; however, no argument may be raised with the author's area of focus, since he covers this admirably.

The second point for the potential reader to understand concerns the book's title. The book is an "introduction to ceramics" only if the reader has a solid background in physics and chemistry. A casual reader will find the subject matter somewhat advanced, particularly if he has been out of school more than a few years and has missed the present trend in emphasis toward the physical chemistry of materials. Possibly a different title would have been less misleading.

Professor Kingery's book is highly recommended to the materials engineer as a thorough study of the science of ceramic materials.

Metals Handbook, 8th Edition, Vol I: Properties and Selection of Metals. *Edited by Taylor Lyman. American Society for Metals, Novelty, Ohio. Cloth, 8¼ by 10⅞ in., 1300 pp. Price $30*

Those who are familiar with the *Metals Handbook*—and every metallurgist and design engineer con-

*Professor of Materials Engineering, Dept., of Chemical and Metallurgical Engineering, University of Michigan.

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TECHNICAL LITERATURE

cerned with metals should own one—will welcome the 8th edition of this well-known reference work. The revision is especially welcome at this time because it covers practically every advance made in the metals field since 1948 (when the previous edition was published).

Emphasizes selection

Particularly welcome is the new accent on the practical use of information. Reflecting the fact that this is a specialized book devoted almost exclusively to the selection and properties of metals, almost the entire first half of the 1948 edition has been so radically revised as to be unrecognizable. Separate sections on heat treating, testing, joining, methods of manufacture, etc., have been eliminated. Where applicable, of course, such information has been integrated into unified texts dealing with specific families of alloys.

Three selection criteria

The approach adopted is one that fits well with today's concept of the materials engineer. The man who is familiar with only a small group of metals or fabricating processes is often at a disadvantage. The *Handbook* faces the problem of metals selection squarely and has analyzed the problems in terms of three principal criteria: specific engineering properties, fabricability or processing, and cost. Thus, the book avoids the conventional mixture of chemical composition tables, selected properties charts, and generalized text. Rather, it combines tables and charts into a series of articles on selection of metals for 1) specific properties (e.g., yield strength, fatigue resistance, notch toughness, etc.); 2) processing and economy (e.g., selecting steel for deep drawing, selecting metals for economy in machining, etc.); and 3) various metal forms (e.g., selecting materials for bolts, chemical processing equipment, electrical contacts, etc.).

In principle, the major differences between the 1948 and 1961 editions are the increased emphasis on easily accessible data and the closer relation to engineering practice. Beyond this, the new edition provides 2½ times as many pages on selection and properties of metals, and nearly six times as much numerical information in the form of charts, graphs, and tables. The new edition was compiled by 1300 contributors and contains 6700 illustrations, 1841 tables, 1500 examples, 2806 definitions, and data compilations on 456 alloys. No engineering library would be complete without it.

Reports

Fracture testing FRACTURE TESTING OF HIGH-STRENGTH SHEET MATERIALS UNDER CONDITIONS APPROPRIATE FOR STRESS ANALYSIS. *G. R. Irwin, U. S. Naval Research Laboratory. July '60, 48 pp. Available from Office of Technical Services, Dept. of Commerce, Washington 25, D. C. Price $1.35 (PB 161 474)*

Describes and justifies a method for testing the fracture toughness of thin sheet materials.

Steel forgings HIGH STRENGTH STEEL FORGINGS. *H. J. Henning and F. W. Boulger. Defense Metals Information Center, Battelle Memorial Institute. Jan '61. 62 pp. Available from Office of Technical Services, Dept. of Commerce, Washington 25, D. C. (PB 151102)*

Describes forging characteristics, design limitations, dimensional tolerances, quality control problems, and mechanical properties of forgings made from martensitic steels heat treated to strengths ranging from 240,000 to 300,000 psi.

Protective coatings OXIDATION BEHAVIOR AND PROTECTIVE COATINGS FOR COLUMBIUM AND COLUMBIUM-BASE ALLOYS. *W. D. Klopp, Defense Metals Information Center, Battelle Memorial Institute. Jan '60, 97 pp. Available from Office of Technical Services, Dept. of Commerce, Washington 25, D. C. Price $2.25 (PB 151 080)*

Covers three main areas: 1) reaction of columbium with oxygen, air or nitrogen; 2) oxidation behavior data for 20 binary and 7 ternary alloys; and 3) coating requirements, types of coatings available, and methods of application.

Tensile and creep data SELECTED SHORT-TIME TENSILE AND CREEP DATA OBTAINED UNDER CONDITIONS OF RAPID HEATING. *D. P. Moon and W. F. Simmons, Defense Metals Information Center, Battelle Memorial Institute. June '60, 88 pp. Available from Office of Technical Services, Dept. of Commerce, Washington 25, D. C. Price $2.25 (PB 151 088)*

Short time elevated temperature strength data obtained under conditions of rapid heating are given for 28 sheet alloys, including three aluminum alloys, six titanium alloys, two alloy steels, three tool steels, and eight superalloys. A bibliography contains references to 121 reports and articles on test methods, equipment, and very-short-time data for these and other materials.

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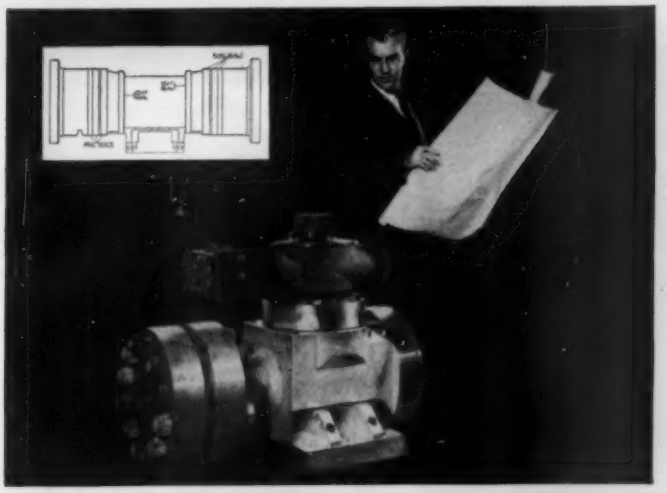

The five-ton valve above is used to test a rocket engine fuel line. Its flow valve meters a highly corrosive mix—liquid oxygen and kerosene fuels—at temperatures below −300°F. and pressures up to 5,000 lbs. psi. Yet valve leakage in this precision assembly is zero. And the designer credits corrosion-blocking KEL-F Brand Dispersion coating on valve seat rings and seals, at eight critical points (see diagram above).

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PROPERTIES PROFILE

ON

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KEL-F Dispersions were developed to extend the protection of KEL-F Plastic to the surfaces of parts that do not lend themselves to fabrication from molded plastics because of size, design or construction. Consisting of fine particles of KEL-F Plastic suspended in a volatile organic liquid, KEL-F Dispersions can be applied to many metallic and certain non-metallic surfaces by spray, spread or dip coating. Heat fuses the dispersion into a tough, permanent protective coating with high tensile and compressive strength, good elongation, and excellent abrasion and wear resistance.

TYPES OF DISPERSIONS	Type KF-625	Type KF-602
Application Method	Spray	Spread, flow, dip
Pounds solids per gallon	3.6	3.4
Approximate square foot coverage per gallon (per mil thickness)	295	330
Viscosity, Zahn G-1 Cup, 75°F. secs.	34	—
Viscosity, Brookfield, 75°F. cps.	—	9-10,000
Thinners	Xylene	Amyl Acetate

PROPERTIES

Chemical resistance. KEL-F Dispersion coatings resist attack by strong acids, alkalies, gases and oxidants and extremely high temperatures. This makes them outstanding corrosion protectors for aerospace equipment.

Anti-stick characteristics. Glues, inks, paints, greases, waxes, rubber or casting resins will not readily adhere to coatings of KEL-F Dispersions. Coating surfaces of aerospace equipment with KEL-F Dispersions reduces clean-out and shut-down time.

Temperature resistance. Temperature-resistant KEL-F Dispersion coatings have an operational range of 710°F. (−320°F. to +390°F.).

Dielectric strength. KEL-F Dispersion coatings have high dielectric strength at low to very high operational frequencies and temperatures. Non-wetting surfaces permit no moisture absorption, minimize flashover.

For full information on KEL-F Halofluorocarbon Dispersion coating systems, send for our brochure on the subject, or write, describing your area of interest to 3M, Chemical Division, Department KAR-61, St. Paul 6, Minnesota.

CHEMICAL DIVISION

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This Sandusky Centrifugal Casting—one of four produced for Westinghouse Atomic Equipment Department—meets radiographic, intergranular corrosion, and all other rigorous chemical and physical tests.

ONE SANDUSKY CENTRIFUGAL CASTING ...makes 4 giant stator shells

Specified by Westinghouse for 4 canned motor pumps soon to be integral parts of reactor system in Yankee Atomic Electric Plant in Rowe, Massachusetts

One king-size 17-ton Sandusky casting supplied the main motor bodies (stator shells) for the four pumps being built by Westinghouse, each to handle 23,600 g.p.m. of pressurized water through the reactor core.

The 25-foot-long Sandusky casting was centrifugally spun of a modified CF-8 (Type 304 L) stainless steel, then machined by Sandusky to a 3″ wall thickness, 31½″ on the O.D. This huge casting was hydrostatically tested to 3800 psi before being sectioned into four 68″ lengths.

These stator shells represent another *new and exacting application* for Sandusky Centrifugal Castings—which may offer a practical and economical answer to *your* cylindrical requirements also. They are available in diameters from 7″ to 54″—in lengths up to 33 feet—in heat- and corrosion-resistant stainless, carbon and low-alloy steels and a wide range of copper-base and nickel-base alloys.

Let us show you how Sandusky Centrifugal Castings can help solve your cylindrical problems. Write to us at Sandusky, Ohio.

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SANDUSKY, OHIO Stainless, Carbon, Low-Alloy Steels—Full Range Copper-Base, Nickel-Base Alloys

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Among the important factors in Shell Chemical's decision to make polystyrene were its extensive background in polymers and its raw material position. Two other Shell thermoplastics followed quickly – polypropylene and polyethylene.

BULLETIN:

On May 3, 1960, a remarkable thermoplastics decision was made by Shell Chemical

Read about this Shell decision. And how you can start benefiting today from a major new source of polystyrene, polypropylene and polyethylene that resulted from it.

On MAY 3, 1960, Shell Chemical, a company long basic in styrene monomer and SBR rubber, decided to combine the two in full commercial production of Shell high impact polystyrene. Why was this remarkable?

A revealing fact on polystyrene

The condition of the polystyrene market was not attractive. There was oversupply from some of America's finest companies. The field was mature and Shell was starting late.

One revealing fact offset this situation. *Shell, with its excellent background in polymer chemistry—as exemplified by Shell Isoprene Rubber, the industry's first commercially produced synthetic/natural rubber—could make positive contributions to the thermoplastics field in the form of new products.* But Shell would be severely handicapped without a thorough understanding of how the thermoplastics market works and what it wants.

Result? Shell's decision to go full speed ahead with high quality general purpose, medium and high impact Shell polystyrenes, plus a rapidly expanding technical sales force.

80 million pounds of polypropylene

Two other thermoplastic developments followed quickly.

One, Shell's announcement in October, 1960, for an 80 million pounds a year polypropylene plant with customer service and research facilities to be built near Woodbury, N. J. Two, an arrangement by which Shell will resell limited quantities of polypropylene until this plant comes on stream.

Custom-made polyethylene

And this, in turn, led to a third important thermoplastic.

In order to round out a complete line of thermoplastics, Shell Chemical, in January, 1961, made arrangements to supply the industry with the highest quality custom-made polyethylenes.

How to start benefiting

Thus, within 8 months, Shell became an important factor in three plastics: Shell polystyrene, Shell polypropylene and Shell polyethylene.

The next 8 months should be even more important. Shell will be going full speed ahead searching for new polymers you want.

Now is the time to let Shell's technical representative know your needs. Tell him about them on his next visit or write Shell Chemical directly at:

42-76 Main St., Flushing 55, N. Y. FLushing 3-4200; 20575 Center Ridge Rd., Cleveland 16, O. EDison 3-1400; 6054 West Touhy Ave., Chicago 48, Ill. SPring 4-6711; or 10642 Downey Ave., Downey, Calif. SPruce 3-0601.

A Bulletin from

Shell Chemical Company

SHELL

Plastics and Resins Division

For more information, turn to Reader Service card, circle No. 441

Monsanto introduces...

LUSTRAN TYPICAL PERFORMANCE DATA			LUSTRAN I							LUSTRAN A	
			MOLDING				EXTRUSION*				
PROPERTIES	Test Conditions	Units	210	410	610	710	261	461	761		ASTM
Tensile											
Stress at Yield	73° F.	psi	9,000	8,000	6,800	6,200	8,000	6,000	5,100	11,000	D638-58T
Stress at Failure	73° F.	psi	6,800	5,200	5,400	5,200	6,300	5,300	4,500	11,000	D638-58T
Elongation at Yield	73° F.	%	3.0	3.0	3.0	3.3	2.2	2.3	2.5	3.0	D638-58T
Elongation at Failure	73° F.	%	45**	55**	55**	70**	25	35	45	3.0	D638-58T
Modulus in Tension	73° F.	psi	420,000	380,000	330,000	300,000	380,000	320,000	290,000	520,000	D638-58T
Flexural											
Maximum Stress at Yield	73° F.	psi	13,700	12,000	10,000	9,200	12,500	10,000	8,500	15,600	D790-59T
Maximum Deflection at Yield	73° F.	inches	0.90	0.47	0.45	0.45	0.3	0.3	0.3	0.32	D790-59T
Modulus in Flexure	73° F.	psi	450,000	400,000	350,000	320,000	400,000	360,000	320,000	—	D790-59T
Impact Strength											
Izod ½" x ½" Bar Mld. (.010" Notch Radius)	73° F.	ft. lbs./in. of notch	1.1	1.8	3.8	4.9	0.9XX	1.8XX	3.8	0.6	D256-56
	0° F.	ft. lbs./in. of notch	0.8	1.2	1.6	2.0	0.6XX	0.9XX	1.5	—	D256-56
	−40° F.	ft. lbs./in. of notch	0.6	0.7	0.9	1.4	0.6XX	0.8XX	1.1	—	D256-56
Izod ¼" x ½" Bar Mld. (.010" Notch Radius)	73° F.	ft. lbs./in. of notch	1.3—4.0	2.5—5.5	4.0—6.0	6.0—8.5	—	—	—	0.4	D256-56
	0° F.	ft. lbs./in. of notch	0.7—1.2	1.1—1.6	1.4—2.0	2.0—2.6	—	—	—	—	D256-56
	−40° F.	ft. lbs./in. of notch	0.6—0.8	0.7—1.0	0.9—1.2	1.1—1.8	—	—	—	—	D256-56
Hardness											
Rockwell	73° F.		R-119	R-113	R-108	R-103	R-113	R-106	R-103	(M85-M90) R-122	D785-51
Thermal											
Deflection Temp. under Load Unannealed ½" x ½" Bar	264 psi	°F.	185	183	178	177	196+	192+	187+	197	D648-56
Physical											
Specific Gravity (Naturals)		—	1.07	1.06	1.05	1.04	1.07	1.06	1.04	1.08	D792-50

*Data on Extruded Sheet **Monsanto Test +Data on Molded Samples XX½" x 0.115" Bar-Sheet

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breaks through the price-performance barrier

LUSTRAN is a high strength plastic material supplied at low cost in performance-tailored formulations. It provides a balanced combination of light weight, unusual toughness and durability, excellent thermal stability and colorability.

With LUSTRAN, you will be able to design the right level of effective strength at the right cost into every product. See for yourself—compare the typical performance characteristics of the LUSTRAN formulations shown against the material requirements of those designs you now have on the boards. You can select a LUSTRAN formulation with *four* times the impact resistance of rubber modified styrene and *ten* times that of general purpose styrene. And, at zero degrees fahrenheit, a ⅛-inch thick 24-inch square sheet withstands the shock of a 6 pound ball dropped 48 inches. LUSTRAN has superior rigidity, excellent surface and gloss appearance, abrasion and chemical resistance and is available in a vast color range.

LUSTRAN—a unique molecular arrangement of styrene and other monomeric materials—has been successfully injection molded into parts weighing as much as 3½ pounds and vacuum formed in deep drawn parts weighing up to 11 pounds. It promises new design possibilities for components and housings for business machines, automobiles, refrigerators, radios and other appliances, packages, luggage and toys. Wherever the performance-cost balance is critical, LUSTRAN can help you. For more data, write to Monsanto Chemical Company, Plastics Division, Department 822, Springfield 2, Massachusetts.

LUSTRAN: Reg. U.S. Pat. Off.

Monsanto

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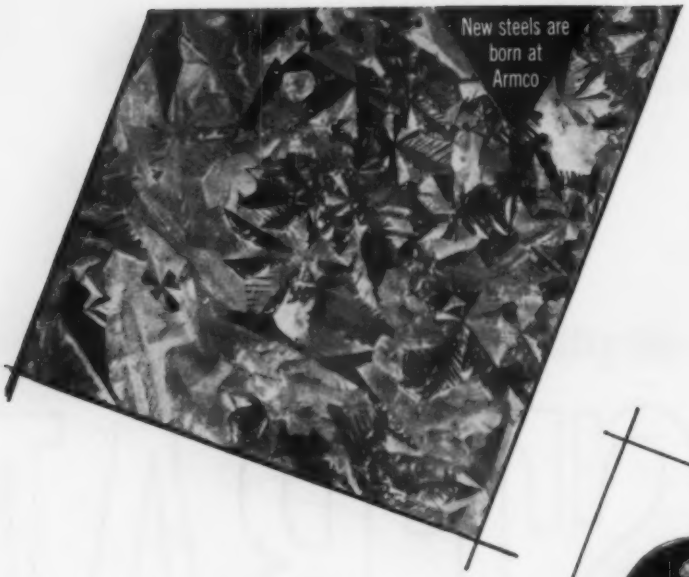
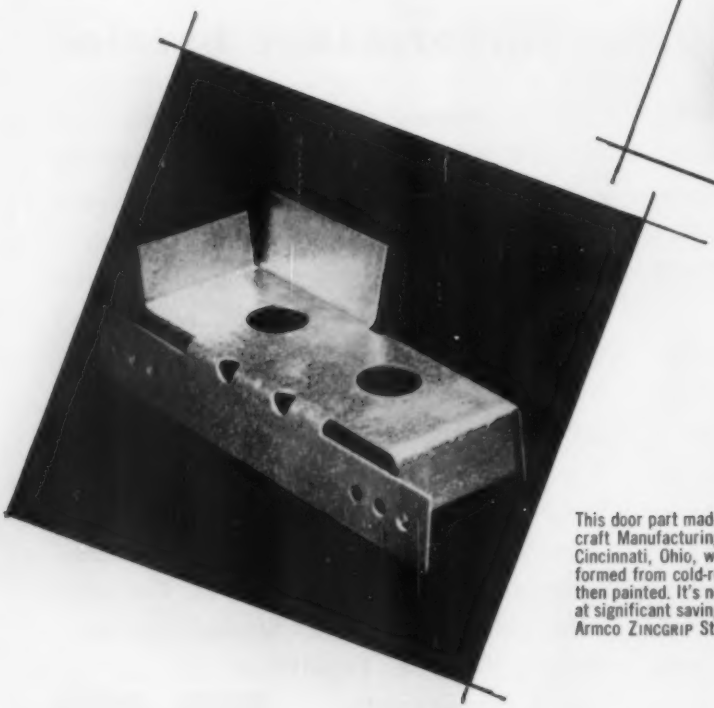


Coating on



This door part made by Steelcraft Manufacturing Company, Cincinnati, Ohio, was previously formed from cold-rolled steel, then painted. It's now fabricated, at significant savings, from Armco ZINCGRIP Steel.

ZINCGRIP gives products durable protection at average cost of about 2⅓¢ per square foot

Can you match this with painting or plating?

Unseen structural parts are often protected from corrosion by painting or plating cold-rolled or hot-rolled steel. Yet with Armco ZINCGRIP® Steel, you can give your products the durable protection of a full-weight two-side coating of zinc at an *average cost of about 2⅓ cents per square foot.* Important cost savings are realized daily by manufacturers who take advantage of this economical protection.

Severe fabrication is no obstacle. You can work mill-coated ZINCGRIP to the limit of its ductile steel base. The tight zinc coating will not flake or peel.

If you paint or plate for protection from corrosion, it will pay you to investigate Armco ZINCGRIP Steel. Let us help you compare your costs for a painted or plated steel part with costs for the same part made from durable ZINCGRIP. Just fill in and mail the coupon.

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☐ Send me your Application Data Bulletin
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Steel

Use this label to identify your products made of strong, durable steel.

Check these cost comparisons

Steel Thickness	Cost of* ZINCGRIP Coating c/sq. ft. of sheet	Typical** Cost of Painting c/sq. ft. of sheet	Savings with ZINCGRIP c/sq. ft.
.025	1.83c	3.25c	1.42c
.050	2.72	3.25	.53
.075	2.51	3.25	.74
Average . . .	2.35c	3.25c	.90c

*Coated both sides **Painted both sides

Computations based on coils 24" to 36" wide. ZINCGRIP coating costs are additional costs beyond price of cold-rolled steel. Due to variations between thicknesses, cost of zinc coating in table varies somewhat even though it's the same full-weight coating. Paint costs are figured on typical dip-painting or flow-coating methods and include cost of metal preparation, paint, labor and overhead of painting operations. Some paint costs are lower than these; many are more.

ARMCO **Armco Division**

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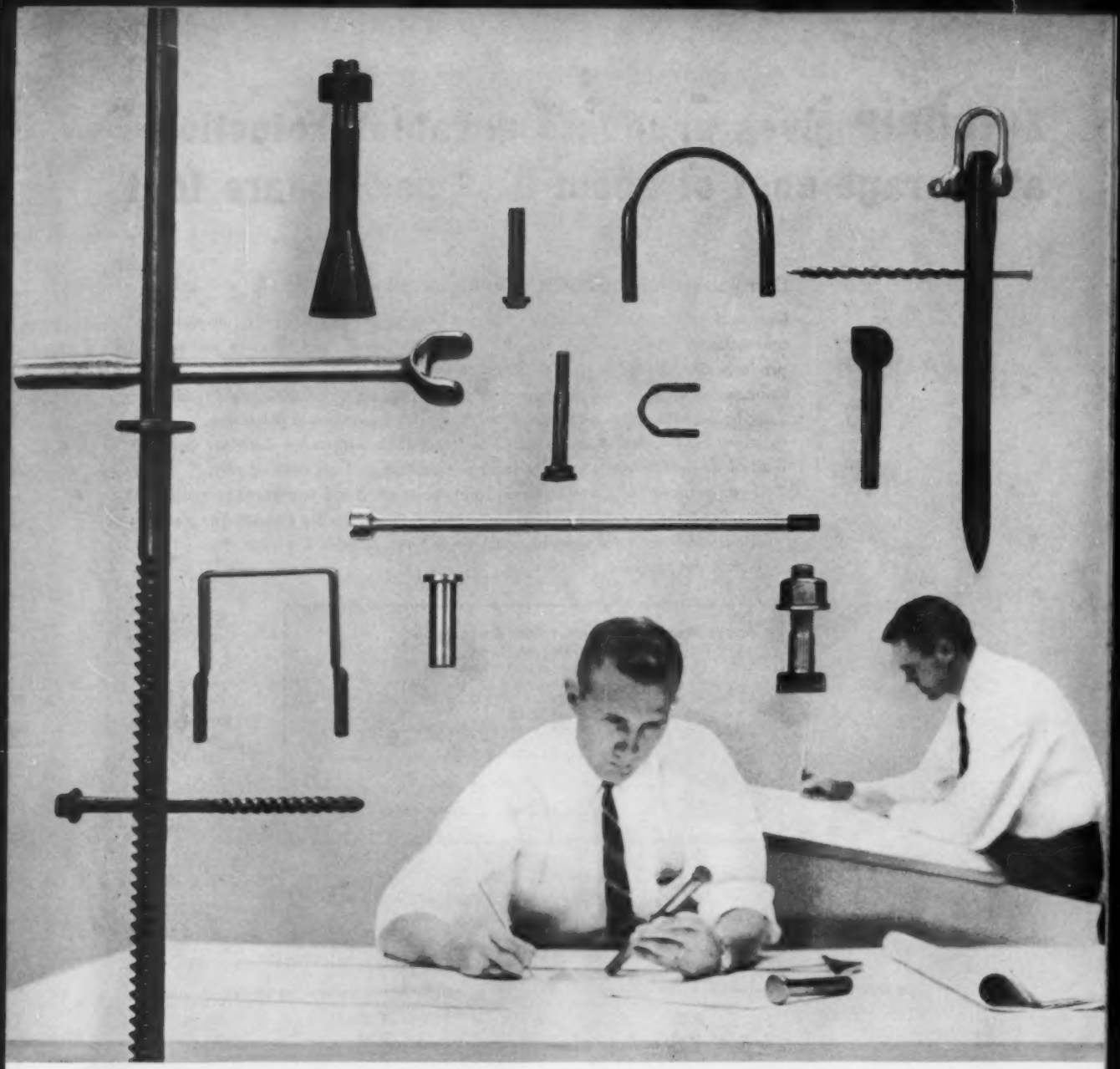

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Every one of these specialty products was made for a specific application from drawings or specifications supplied by our customer. Translating your design into a finished part is seldom easy. But if the job can be done . . . Bethlehem fastener engineers can do it.

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working with

Du Pont Zytel®

one of Du Pont's versatile engineering materials

New lockset designed with ZYTEL® NYLON RESIN offers easy installation...lifetime service...economical production

This lockset looks better, lasts longer than the metal one it replaces—and it took a material with remarkable properties to make it. It took a material that is exceptionally tough and abrasion-resistant, a material with friction so low as to make lubrication unnecessary, a material that is rust- and corrosion-proof, a material that can be economically molded to close tolerances in large quantities, and one that requires little or no finishing.

In short, it took Du Pont ZYTEL nylon resin.

In this radical design innovation, almost all working parts except the knobs are molded of tough Du Pont ZYTEL. Installation of the lockset is made foolproof; round and square sleeves mate with round and square posts. The entire set is held by two double lead bolts that drive directly into holes in the chassis sleeves. And a self-aligning latch case lets the installer swivel the latch to the right or left of the central lock assembly for bevel-edged doors or for improper boring. In action, the bolts of ZYTEL were tested up to 1,500,000 cycles—equivalent to more than 100 years of normal household use—without perceptible wear. And the lockset functions smoothly and quietly without lubrication. Molded by Nylon Products Corp., affiliated with F. J. Kirk Molding Co., Clinton, Mass., for Lockwood Hardware Manufacturing Co., of Fitchburg, Mass., the parts are economically mass-produced, need virtually no finishing operations.

On the following page, you will find further illustrations of the design improvements and cost reductions made possible by the complete line of ZYTEL nylon resins.

DU PONT

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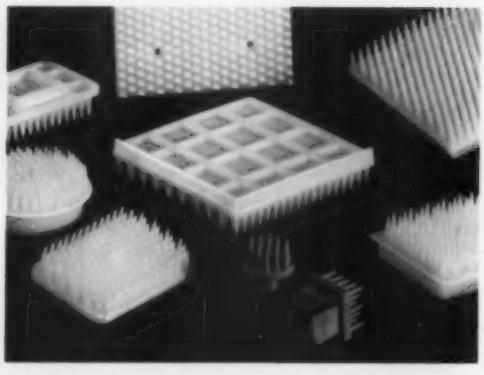
BETTER THINGS FOR BETTER LIVING ...THROUGH CHEMISTRY

working with

Du Pont Zytel®

one of Du Pont's versatile engineering materials

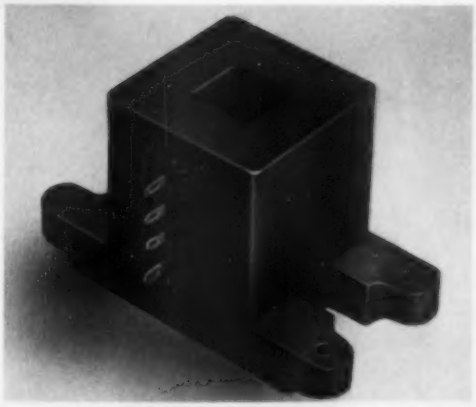
When installed in a teletypewriter, these wheels will be subjected to steady abrasion on the typewriter ribbon. The wheels are molded of ZYTEL, because of its impact and abrasion resistance, as well as its moldability and the exacting tolerances which can be held. (Molded by General Die Mold, Chicago, Illinois, for Kleinschmidt Division of Smith-Corona Marchant, Inc., Deerfield, Illinois.)



Heavy loads are supported by small carpet protectors made of ZYTEL. Support is distributed by the many tiny nylon "icicles" that reach the floor between the tufts of rug—instead of crushing the rug under the object's weight. Factors in the choice of ZYTEL were strength and resistance to creep or cold flow. (By United States Caster Cup Corporation, Kansas City, Mo.)

Parts of ZYTEL® NYLON RESIN resist abrasion, stand up to impact, mold easily

A large part of the ZYTEL success story is attributable to its versatility of application. In complete operating units or in working parts, its remarkable array of properties—mechanical, chemical, electrical and processing—makes it a natural problem solver in design. Your own design may well benefit from the contribution of a particular composition of ZYTEL. To learn more about the performance of the different compositions of Du Pont ZYTEL, just complete and mail the coupon below.



Coils encapsulated in ZYTEL offer high dielectric strength with relatively thin coatings. Coils are protected against humidity, acids, alkalies, and oils. The coatings can also be used as bearing surfaces, as in solenoids and contactors, thanks to the abrasion resistance and low friction of ZYTEL nylon resin. The mounting feet shown are molded as an integral part of the encapsulation. (Processed by Anderson Controls, Franklin Park, Illinois.)

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ZYTEL® *nylon resins*

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Designing For Cost Conscious People? Then Read . . .

Lockheed F-104A Starfighter with aluminum surfaces protected by Iridite 14-2.

How IRIDITE® Helps Lockheed Cut Aluminum Finishing Costs

Nine years ago, Lockheed switched from anodizing to Iridite chromate conversion coatings. That year, they saved over $40,000 in materials and manpower.

Today, Lockheed is still saving money with Iridite 14–2. Here's how:

Process time is reduced from 45 minutes to a maximum of only 5 minutes. Three times as much work is processed in a single run. Easy-to-load baskets, replacing costly anodizing racks, save $15,000 per year. Expensive electrical equipment is eliminated because Iridite is a simple chemical dip.

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More than likely, Iridite can save you money and give you better finishing results than your present method. Discuss it with your Allied Field Representative. Or, write for literature.

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West Coast Licensee for Process Chemicals: L. H. Butcher Co. • European Agent: Stora Granberger, Stergatan 10, Stockholm, Sweden

Chemical and Electro chemical Processes, Anodes, Rectifiers, Equipment and Supplies for Metal Finishing

IRIDITE® Chromates | IRILAC® Coatings | ISOBRITE® Brighteners | ARP® Supplies | WAGNER Equipment

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Malleable Puts More Muscle in Machinery

In the agricultural equipment field, reputations depend on building products that can take rough treatment . . . and give real value. To do it, agricultural equipment manufacturers rely heavily on Malleable iron castings.

Malleable's excellent ductility and shock resistance mean longer life and fewer problems than obtainable with fabrications. Low start-up cost for small quantities also is vitally important in this competitive industry.

Put more reputation-building quality into your products at less cost with Malleable. For design assistance or quotations, call any company that displays this symbol —

PROBLEM-SOLVING IDEAS are yours free in Data Unit No. 115. For your copy, ask any member of the Malleable Castings Council, or write to Malleable Castings Council, Union Commerce Building, Cleveland 14, Ohio.

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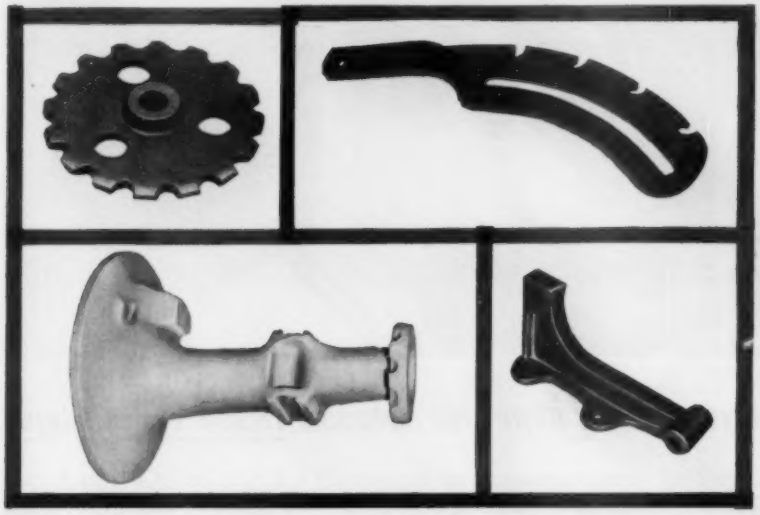
CASTINGS COUNCIL

The versatility of Malleable castings is reflected in the variety of ferritic and pearlitic Malleable tractor parts, from the tough, dependable front axle bar to bolsters, lift arms, clamps, clevises, hitches, hinges, foot pedals, transmission planetary carriers and clutch parts.

No machining or hardening is required on this Malleable chain sprocket. It replaces a part cut from steel plate to which a hub was welded. Cost was reduced 12%. Tests verified the excellent performance of the malleable part, and led to a review of the company's entire manufacture of chain sprockets.

Field failures stopped as soon as the manufacturer of this plow quadrant began using a Malleable casting in place of a welded fabrication. This part looks better, works better, and quality is uniform in every piece. Yet the Malleable quadrant costs 22% less than the fabrication.



The strength of Malleable is illustrated by farm tractor rear axle housings. They must absorb the constant shock and strain exerted as heavy implements are dragged over rough fields. Toughness, ease of machining and economy make Malleable first choice for this demanding application.

Costs dropped 59% when this disc harrow ram anchor was converted from a weldment to a Malleable casting. Malleable's shock resistance combined with a better design resulted in a part able to withstand constant punishment.

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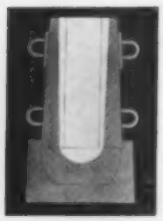
MEL-TROL®..the important extra you get in *Carpenter* Induction Vacuum Melted Alloys!



New, more refined melting processes such as Carpenter's VACUMELTROL® (induction vacuum) or CONSUMET® (consumable electrode) answers industry's need for better, more dependable steels for critical applications. But in induction vacuum alloys, Carpenter goes a step further. It's called MEL-TROL and it starts with an entirely new, patented mold that builds essential core-to-surface uniformity right into the ingot. Harmful impurities in the molten steel float to the top while the ingot solidifies . . . then are discarded. The result is more complete freedom from segregation and centerline weakness, and the most uniform, dependable alloys you can buy.

Benefits to you: *Improved alloy quality such as cleanness and soundness result in better forgeability, improved machinability and cold forming properties. You get more accurate forgings with better finishes . . . fewer rejects . . . faster production . . . and, most important, true predictable performance in critical alloy components. A wide range of these more uniform, more workable alloys is now available for high temperature and other critical applications. Call your nearby Carpenter representative for the whole story about MEL-TROL and what predictable performing steels can do for you.*

Carpenter steel

you can do it ***consistently*** better with Carpenter Specialty Steels for specialists

The Carpenter Steel Company, Main Office and Mills, Reading, Pa.
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Precious metal contacts in pure or alloyed forms of silver, platinum, palladium and gold provide unmatched resistance to atmospheric corrosion, deformation, arc erosion, binding and metal transfer. Baker high-reliability precious metal contacts are supplied as wire, rod, sheet and in a complete line of fabricated forms. Facilities are also available for manufacture to your specifications.

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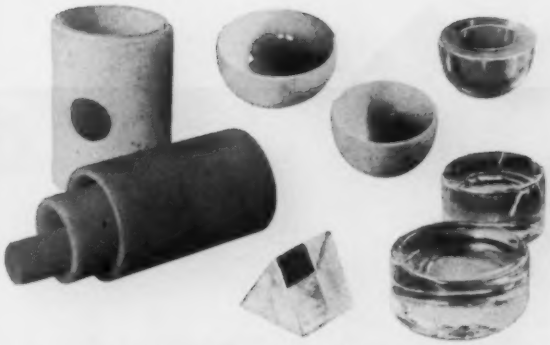

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Amersil manufactures and fabricates high purity fused quartz for ultraviolet transmission application, laboratory ware and production equipment. These products include standard apparatus, plain tubing in many intricate fabrications, crucibles, trays, cylindrical containers and piping in a full range of sizes up to 25" in diameter. Ingots and plates are available in general commercial quality as well as in special optical grades. Amersil engineers are also prepared to assist in developing fused quartz and silica equipment for special requirements.

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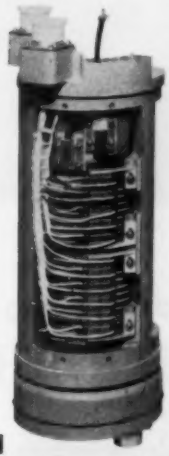

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Complete facilities, metallurgical and engineering services are available for design and manufacture of slip ring assemblies to critical specifications, ranging in diameter from 1" to 48" and larger—for General Purpose, Radio Frequency and Video Ring Circuits, High Speed Instrumentation, High Voltage Ring Circuits and Power Pulse Slip Rings. A slip ring data file is available —write for your copy.

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GLX-W COLUMBIUM-TREATED CARBON STEEL CUTS DEAD WEIGHT 10% IN NEW

VERSATILITY...
That's the Beauty of Steel

Bringing important new economies to rail shipment of automobiles, this new tri-level auto carrier holds twelve standard cars or mixed loads of 14 standards and compacts. Capacity is increased up to 75%. A unique system of hydraulically positioning the vehicles on three levels gives a clearance of only 16 feet 8 inches, permits use in areas formerly limited to bi-level unit operation because of clearance requirements. ◆ Key feature of the Multi-Car Carrier is the movable decks on which the cars ride. Made of GLX-W columbium-treated steel, the decks are raised and lowered by built-in hydraulic lifts, actuated by a portable power unit. Here light weight was essential, in order to reduce the operating power requirements. Yet great strength was necessary, too, to support the payload. Finally, design of the decks called for eight bends in each section. So formability was also a must. ◆ GLX-W met and exceeded all these requirements. It gives 50-100% greater strength than mild carbon steel, so builder Whitehead and Kales could get the required strength with less weight. Deck operating units need less power,

Great Lakes Steel is a Division of

Multi-Car Carrier built by Whitehead and Kales for Multi-Car Corporation, Detroit, Michigan

TRI-LEVEL AUTO CARRIER

and total weight is reduced approximately 5,000 pounds or 10%. Production is more economical, too, because the ductility and formability of GLX-W permits four of the bends in the deck to be performed in one press operation. ➔ The GLX-W series of high-strength steels consists of fine-grained, semi-killed mild carbon steels, treated with varying amounts of columbium. The high strength of GLX-W permits designers to reduce the amount of steel and effect considerable cost savings when replacing mild carbon steel. GLX-W steels have a low carbon content and are readily weldable and formable. GLX-W steels are available at four minimum yield strength levels: 45,000, 50,000, 55,000 and 60,000 p.s.i. and in sheets, plates and bars. For complete technical information, write Great Lakes Steel Corporation, Product Development, Dept. MDE-9, P. O. Box 7310, Detroit 2, Michigan.

GLX W PATENT PENDING

A PRODUCT OF

GREAT LAKES STEEL

Detroit 2, Michigan

NATIONAL STEEL CORPORATION

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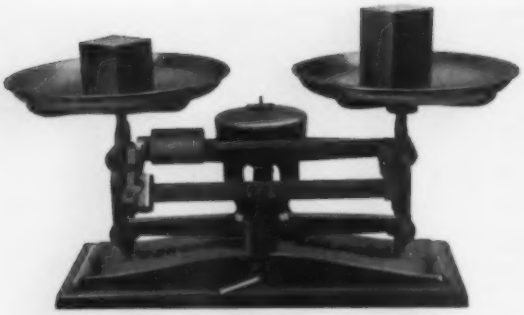
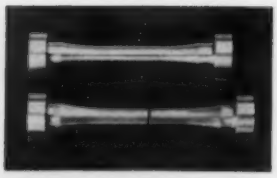
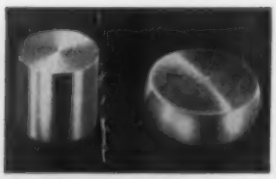


SPECIFIC GRAVITY 17.0 g/cc—50% heavier than lead



TENSILE
⅛" diam. x ½" gage length
ultimate tensile 135,000 psi
yield 90,000 psi
elongation 15%



COMPRESSION
½" diam. x ½" long
load 500,000 psi
change in length 52%
(no cracking)

TRANSVERSE BEND
¼" x ¼" x 1½" span
load 280,000 psi
deflection .232"

DUCTILE
.118" bar before rolling
.102" bar after rolling
.016" reduction in thickness
13.6% reduction in thickness

THESE TYPICAL PARTS INDICATE THE EXCELLENT MACHINABILITY OF KENNERTIUM

KENNERTIUM* has exceptional properties that solve many materials problems

Kennertium, a new heavy tungsten alloy, offers a number of outstanding properties not available in other high-density alloys on the market today.

These superior features include high tensile strength; elongation up to 15% or higher; unusual compression qualities; Young's Modulus of Elasticity of 43,000,000 psi; plus good machinability and other properties to help designers meet many exacting materials requirements.

Kennertium is available in virtually any configuration—and in solid sections up to 10 inches in diameter and 20 inches long for machining to required parts. Cylinders several feet long, or thin rings up to 15 inches in outside diameter, can be processed.

For more information, write for "Kennertium Properties" booklet. And if you have a specific requirement, send dimensional sketch and conditions involved. Our engineers will gladly make recommendations, without any obligation to you. KENNAMETAL INC., Dept MDE, Latrobe, Pa.

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...Partners in Progress

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LEXAN® RESIN MAKES NEW AIR DIFFUSER DESIGN POSSIBLE

A new concept in air distribution—pioneered by Carnes Corporation of Verona, Wisc.—made a reality by LEXAN polycarbonate resin!

In Carnes' design, 6-by-6-inch air diffusers, like those above, form modular units which can be arranged in any desired ceiling pattern. Three different module designs provide complete flexibility in directing air.

"LEXAN resin is the only material we have approved for our diffusers," says Gordon Sylvester, Chief Product Engineer of Carnes. "We tried polystyrenes, polyethylene, nylon and others, but they all fell short in one way or another."

The material for Carnes' diffusers had to meet this combination of requirements: • INJECTION MOLDING for low production cost. LEXAN resin, as a thermoplastic, gave this advantage. • NO HEAT DISTORTION in 225°F. test for handling warm air. In month-long tests of parts, LEXAN resin met this spec. Actually, the resin's rated distortion point is 270-280°F. under load. • DIMENSIONAL STABILITY in use. LEXAN resin was stable. • FLAME RETARDANCE to pass ASTM test. LEXAN resin passed. • COLOR STABILITY and versatility. Although the modules are now a stable white, LEXAN resin offers the possibility of a wide range of colors. • HIGH IMPACT RESISTANCE. Frank Freese, Product and Merchandising Manager for Carnes, really sells LEXAN resin's enormous impact strength. He says "In demonstrating the strength of the modules, we slam them against the wall. It doesn't damage them at all. Metal diffusers would be bent by this treatment."

LEXAN resin has raised the quality of many designs to new levels. It's been substantially reduced in price as new G-E plant facilities have come onstream. Can this tough new thermoplastic help you? Send for design literature. Address General Electric Company, Chemical Materials Dept., Section M-61, Pittsfield, Mass.

LEXAN®
Polycarbonate Resin
GENERAL ELECTRIC

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NATIONAL GRAPHITE
is available in any size, shape and quantity!
Unmachined...graphite is available from minute particles to five ton blocks...in all sizes of square, round, rectangular and cylindrical shapes. Whatever your needs—whether quantity, purity or size, aside from standard or special grades—let National Carbon Company quote on your requirements.
Machined... Graphite is machined economically at National Carbon Company because we have years of experience handling this unique material plus several strategically located modern machine shops. For simple or complex shapes . . . large or small pieces . . . intricate details with close tolerances . . . let National Carbon Company quote the job. For data, contact our representative or the nearest sales office.

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MONO-SHELL

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Turbocharger impeller of C-355-T61 aluminum alloy.

Aircraft valve bodies of 356-T7 aluminum alloy. Wax pattern assembly, MONO-SHELL ceramic-dip slurry after firing, and finished casting.

Misco's capability has met the demand of government agencies and industries for high integrity, high quality ALUMINUM components of maximum physical properties. Significant results have been attained by adapting Misco's MONO-SHELL investment casting process for the production of aluminum components for specific applications.

Investment castings of aluminum alloys

WE WELCOME INQUIRIES ABOUT THIS NEW PROCESS.

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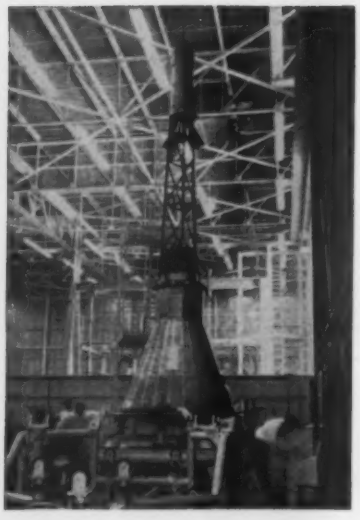
WITH MAN IN SPACE



McDONNELL AIRCRAFT CORPORATION, Lambert Field, St. Louis, Missouri, is prime contractor for the Mercury Capsule, under the direction of the National Aeronautics and Space Administration. Photo shows capsule similar to the FREEDOM VII used in successful launch.

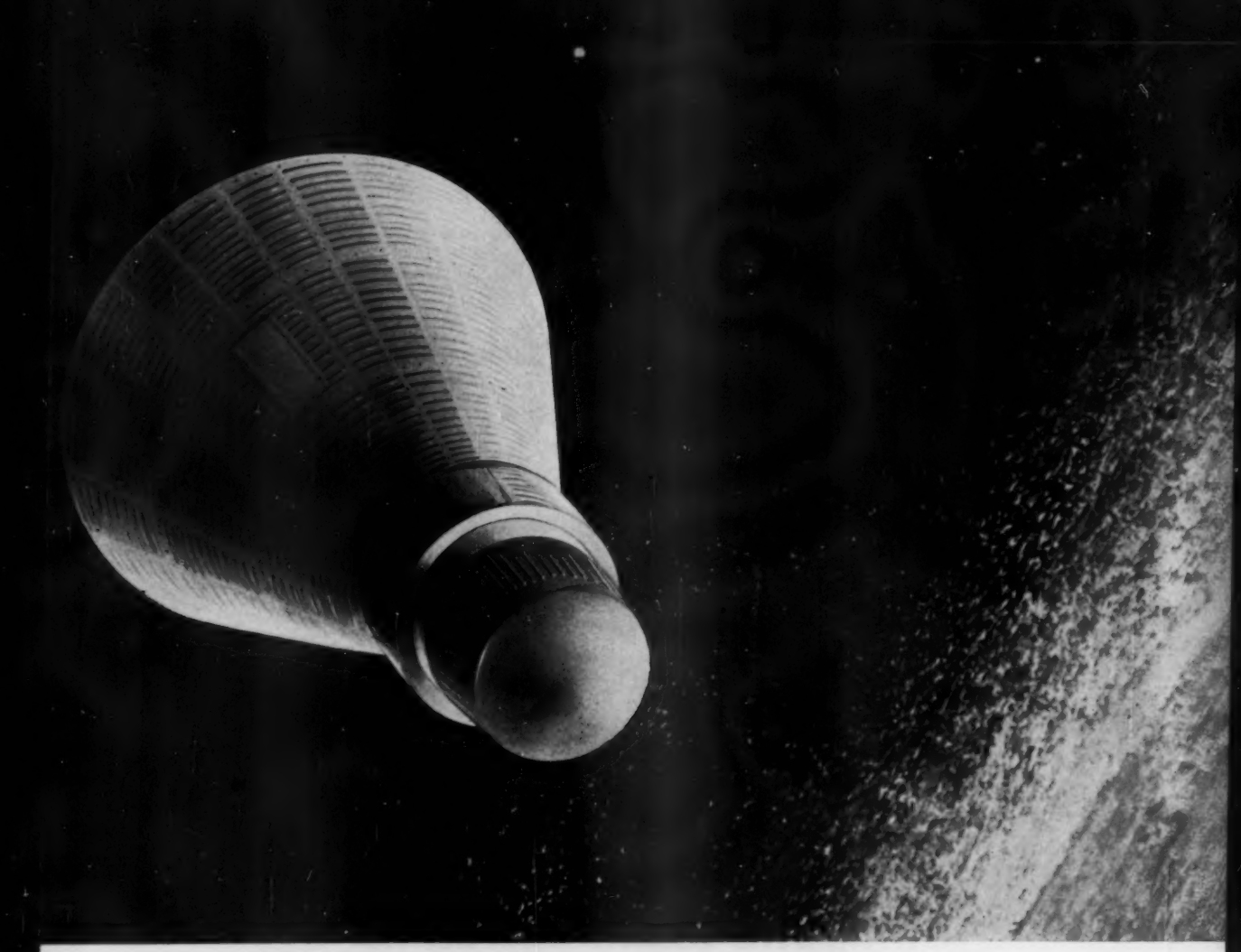
The time: May 5, 1961, 10:34 AM, EDT. *The man:* Commander Alan B. Shepard, Jr., USN, Astronaut. *The event:* launching of the Mercury Capsule with man on a down range step into space. *The metal:* titanium for a combination of strength and lightweight in the vehicle's double wall stringer construction.

A major supplier of commercially pure AMS4901 titanium in the Mercury Project, Republic Steel is the nation's *largest* producer of high-performance metals. Republic is a new source of a complete line of precipitation hardenable stainless steels . . . the only source of continuous rolled stainless sheet up to 60″ wide . . . the largest producer of stainless and alloy steels, and steels for cold extrusion.

To meet the challenge of space, Republic Steel is looking deep into the microstructure of steel . . . pulling facts from the heart of steel . . . aiming at fantastic new steels with tensile strengths even beyond 400,000 psi.

Republic's 3-Dimensional metallurgical teams—composed of mill, field, and laboratory metallurgists—help you select, apply, and process the most economical metals capable of meeting requirements. This is a confidential, obligation-free service. For additional information, contact your Republic representative or mail the coupon on the opposite page.

DESIGN ENGINEERS: Mail the coupon for a copy of Republic's new booklet, *Products For The Design Engineer.* Contains a useful Stainless Steel Selector Chart, and information on Republic High Strength Steels, Titanium, Electrical Steels, Vacuum Arc Melted Steels, and other high performance metals.



VACUUM ARC MELTED METALS . . .

Processed into billets, bars, plates and sheets, strip, or wire, Republic Vacuum Arc Melted Metals are produced in 4,000- to 20,000-pound ingots. The consumable electrode vacuum-melting process improves tensile strength, ductility, fatigue life, and performance at high and low temperatures. Precise control reduces nonmetallic inclusions and harmful gases. Republic helps you select the vacuum-melted metal best suited to requirements: constructional alloy steel, high strength alloy steel, bearing steel, stainless steel, super alloy steel, titanium, or special carbon steel.

REPUBLIC PH STAINLESS STEELS . . .

Republic PH 15-7 MO* for missiles and aircraft offers high ultimate tensile strength with excellent mechanical properties to 1000°F. Republic 17-4 PH* for shafts, gears, pins, and other components requires only a one-hour heat treatment at 900°F to develop its full strength (ultimate tensile strength to 200,000 psi). Republic 17-7 PH* for pressure tanks, bellows, springs, and other applications provides better corrosion resistance than the hardenable grades of chromium stainless. Send for PH Stainless Steel Booklet.

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I would also like more information on:
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LINDE
99.9% Pure
ALUMINA
ABRASIVES
BULOVA WATCH PINIONS (sample shown magnified 100x) now have important surfaces polished to a high precision finish with LINDE alumina abrasives. Actual size is at right

Permit Critical Finishing of ALL Modern Metals with ONE BASIC MATERIAL

No longer need the minuteness of a metal part, or its shape, or its type of metal interfere with the quality of its finish.

All-new LINDE abrasive powders—of 99.9% pure alumina—now permit precision finishing and polishing, as well as sharpening and honing of many metal parts—with *one basic material.*

Depending upon usage, LINDE alumina powders can be used dry, mixed with water or other vehicles to make a thin slurry or heavy paste, or compounded with waxes in convenient stick form. They are uniform in size, thus eliminating levigation in finishing operations. And they are resistant to common acids.

Only two grades of these low-cost, fast-cutting, high-purity white powders are required: LINDE A (*alpha alumina*) for quicker cutting and an unsmeared finish; LINDE B (*gamma alumina*) for somewhat slower cutting but an extremely fine finish.

For details on alumina abrasives as applied to your production problems, write Dept. MI-6, Linde Company, Division of Union Carbide Corporation, 270 Park Avenue, New York 17, New York. *In Canada:* Linde Company, Division of Union Carbide Canada Limited, Toronto 7.

PHYSICAL PROPERTIES

	Type A-5175	Type B-5125
Chemical Formula	Al_2O_3(Alpha)	Al_2O_3(Gamma)
Crystal System	Hexagonal	Cubic
Hardness, Mohs'	9	8
Particle Size approximate (microns)	0.3*	<0.1
Apparent Density (g/c.c.)	0.3-0.6	0.2-0.5
Melting Point	2050° C.	Transforms to Alpha form at high temperatures

*Type C-5250 also available in 1.0 microns (approximate) particle size.

SUGGESTED USES

CHEMICAL: Catalyst Carrier • **ELECTRONICS:** Semiconductor Polishing • **JEWELRY:** Gem Stone and Crystal Polishing; Silver Polishing • **LIGHTING:** Phosphor Preparation • **CERAMICS:** Pure Oxide Ceramics • **METAL FABRICATION:** Finishing of Metal Parts; Knife Sharpening; Microtome Knife Sharpening; Razor Blade Sharpening • **METALLURGY:** Metallographic Polishing • **OPTICAL:** Glass Polishing

LINDE COMPANY
DIVISION OF UNION CARBIDE CORPORATION

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ON CARPETING

ON THE PATIO

These eye-catching products use functionally a basic Nickeloid Metal. The finish of Chromium, Nickel, Brass or Copper is electroplated to a base metal, usually Steel (but often Zinc, Brass or Copper).

Mostly, Nickeloid Metals are supplied in continuous coils in widths up to 24" for modern, low cost fabrication. They're also available in sheets and strips. Optional: bright or satin finishes, plating one or both sides, a galaxy of stunning patterns and crimps.

Quality plating produces metals so durable they can be fabricated, even quite severely drawn or bent. Rejects minimized. For severe stamping, we offer Mar-Not protective coating that is easily peeled off after its job is done.

Which is your preference in modern metals — the clean, flint-hard gleam of Chromium, the warmth of Copper, or the rich radiance of polished Brass? No need to answer now, but consider the galaxy of wonderful products you find everywhere today that employ one of the Nickeloid Metals. These durable, lustrous finishes are not mere lily-gilding. In most instances they are designed INTO the product . . . functionally. We make a raw material that has been given these quality finishes the *automated* way . . . in giant coils in block-long mills. Nickeloid finishes are electroplated to the base metal *before fabrication*, a process as fundamental we believe as the coating of printing papers in rolls *before they are printed*. Three out of five costly manufacturing steps are by-passed. Write for our free Introductory Kit, which includes metal samples — learn the complete story.

AMERICAN NICKELOID COMPANY • PERU 6, ILLINOIS

America's Pioneer Manufacturer of Pre-Finished Metals — Since 1898

Security Engineering, a division of Dresser Industries, Inc., manufacturers of rock bits and tools for the oil and mining industries, depends upon "heat-beating" Cast HU alloy trays to combat years of punishment inside carburizing furnaces.

Cast HU high-nickel alloy carburizing trays... Still on the job after 3 fiery years at 1700°F.

No "vacations" needed for these heat-treating trays used by The Security Engineering Division of Dresser Industries, Dallas, Texas. They're constantly fighting carburizing atmospheres that soon "retire" thin-sectioned trays of lower alloyed materials. Not even the brutal punishment of repeated thermal shock during oil quenching stops these trays. They're made from Type HU* cast high-nickel alloy. (39% Nickel-19% chromium).

3 Years at 1700°F... 24 hours a day, these trays take on incandescent temperatures. Yet they don't scale or flake—thanks to Type HU alloy's superior resistance to carburization (and freedom from sigma phase embrittlement).

Casting cuts initial cost too. Right from the start, cast HU alloy trays save you money. They're easy to make—cast in the design that suits your needs.

Surface film stability—resistance to oxidizing and reducing atmospheres—is an important property of Type HU alloy. So is high creep strength and useful ductility up to 2000°F. And Type HU alloy is one of a family of high-nickel alloys especially effective in heat-treating applications. They've got extra long lives in the 1200-2200°F range.

If you have design problems involving high pressures, high temperatures, and corrosive conditions, find out more about Type HU and the other "heat-beating" alloys in the 72-page booklet, *Heat Resistant Castings, Corrosion Resistant Castings . . . Their Engineering Properties and Applications.* It's a reference book made for your files. Write for your free copy of A-266.

*A.C.I. designation

THE INTERNATIONAL NICKEL COMPANY, INC.

67 Wall Street INCO New York 5, N. Y.

INCO NICKEL

NICKEL MAKES CASTINGS PERFORM BETTER LONGER

For more information, turn to Reader Service card, circle No. 396

PRODUCT-DESIGN BRIEFS FROM DUREZ

- **Plastic bearing material**
- **Making epoxies retard fire**
- **Phenolic for motor housings**

MICRO-PRECISION DIVISION, MICROMATIC HONE CORPORATION

Outwears metal bearings

Loads as high as 50,000 psi don't bother this plastic bearing.

In severe high-load, low-speed tests, it came through 60 million cycles without failure—while ordinary bearings gave up at 50,000 cycles.

What helps make it so rugged? One fact is the material used on the outside to encase the bearing material. The bearing material may be considered an insert which is molded in place in one operation. The support material is *Durez 16771*, a glass-filled phenolic molding compound.

Besides being strong and tough, *Durez 16771* withstands oil, grease, and acid; can't pit, rust, or corrode.

What can you do with an idea-plastic like this? Automotive designers are putting it to work now in oil-pump gears, automatic transmission parts. Check into the places where a tough, high-impact plastic could do a better job than the material you're using. Then ask your molder for more details on *Durez 16771*—or check the coupon for Bulletin D203, which describes the material and its capabilities.

The hardener does it

Could you be looking for an epoxy that retards fire?

Here are two epoxy laminates we made up in the laboratory. Both were exposed to equal flames for 30 seconds. When the flames were removed, one laminate blazed merrily on. The other snuffed out instantly, with slight local charring.

The only difference in composition was in the hardener or curing agent used: at the left, a conventional one; at the right, our HET® Anhydride.

Besides conferring flame retardance, HET Anhydride gives a liquid epoxy resin a high heat-distortion point and superior flexurals at 350°F. It won't stain hands or cause dermatitis. And it costs less than most hardeners.

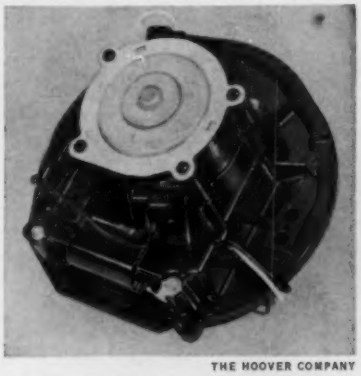
We don't make epoxies, but we'll be glad to send you data on HET Anhydride. Just check the coupon for it.

Housing for life

Here is part of an appliance not built for planned obsolescence.

The new Hoover convertible vacuum cleaner, say its makers, is designed for virtually a lifetime of service. Its engineering represents over 50 years of leadership in a highly competitive field.

It's significant, then, that to enclose the cleaner's two-speed ¼-hp motor, Hoover designers settled on a housing of molded Durez phenolic.



THE HOOVER COMPANY

You needn't look far to find good sound reasons for using phenolic to mount or protect a motor. Phenolic gives lifetime stamina at low cost. It's rugged, non-warping—yet weighs less than other housing materials. On a complex part, it can save you much machining.

Your custom molder can tell you more. Or use the coupon to request fact-crammed Bulletin D400 on Durez molding materials, their properties, and uses.

For more information on Durez products mentioned above, check here:

- ☐ High-impact molding compound *Durez 16771* (Bulletin D203)
- ☐ Epoxy hardener, HET Anhydride (Bulletins 19 and 43)
- ☐ Durez molding materials (descriptive Bulletin D400)

Check, clip and mail to us with your name, title and company address.
(When requesting samples, please use business letterhead)

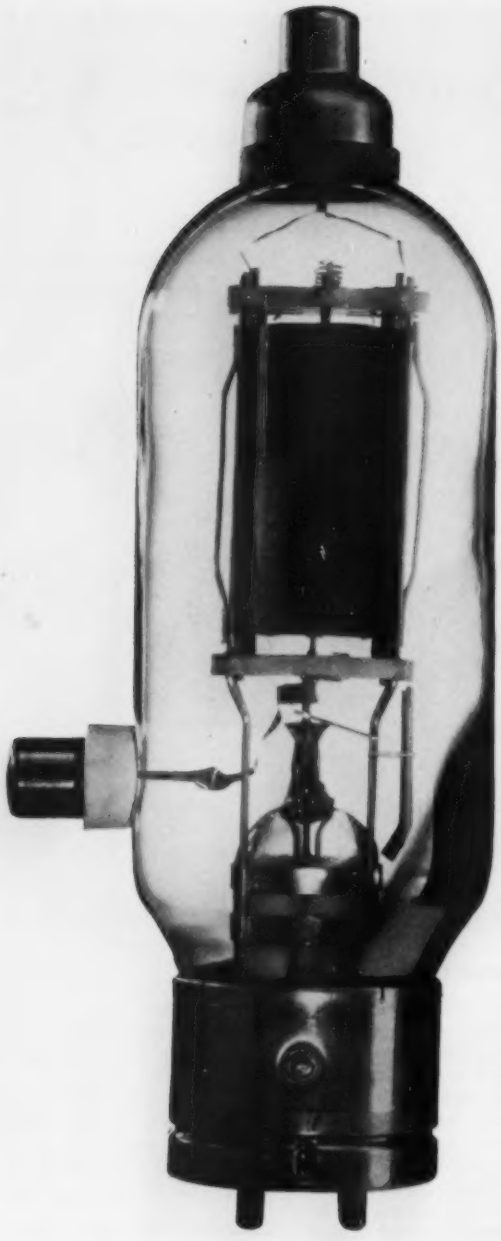
DUREZ PLASTICS DIVISION

1406 WALCK ROAD, NORTH TONAWANDA, N. Y.

HOOKER CHEMICAL CORPORATION

HOOKER CHEMICALS PLASTICS

For more information, turn to Reader Service card, circle No. 406



Ideas in Electronics from Norton

The electronics industry became a giant before it became a baby.

This outstanding growth has been largely due to the development of new materials — *refractory* materials with a great range of electrical properties. The prime source of these *idea refractories* is Norton Company.

For example, refractory fused alumina has high *constant* resistivity, to assure minimum leakage between elements in TV, radio and radar tubes. The same material is a recent innovation for transistor potting. Norton silicon carbide is an essential component in lightning arrestors and other non-linear resistors because of its variable voltage-current relationship. Silicon carbide is also finding new uses in microwave absorption, and as single crystals in high temperature rectifiers and transistors.

Fused magnesium oxide, used in most heating elements for electric ranges, has gained acceptance in such areas as advanced thermocouple design and infrared transmission.

Norton offers a wide choice of superrefined refractories, including oxides, borides, nitrides and carbides, and is ready to work with you in engineering materials to meet your needs. But above all, Norton offers ideas in every field in which refractory materials play a part. Write NORTON COMPANY, Refractories Division, 345 New Bond Street, Worcester, Massachusetts.

NORTON

REFRACTORIES

Crystallizing ideas into products

For more information, turn to Reader Service card, circle No. 326

A TEXTURED FINISH THAT TAKES HARD KNOCKS ...M&T SPRAY-ON VINYLS

Beauty ... distinctiveness ... color ... you get all of these aesthetic qualities with the new vinyl finishes from M&T. But that's only half the story.

These coatings give your product an enduring coat of armor that withstands just about all the physical abuse users can give it. The finish absorbs impact without chipping, doesn't fade, refuses to stain or deteriorate despite constant handling.

You can spray M&T Vinyl Finishes on the most complex parts ... and produce a rich-looking texture on smooth surfaces. Or you can reproduce the most exact detail of finely patterned metal. Or you can put a smooth protective overcoat on smooth metal.

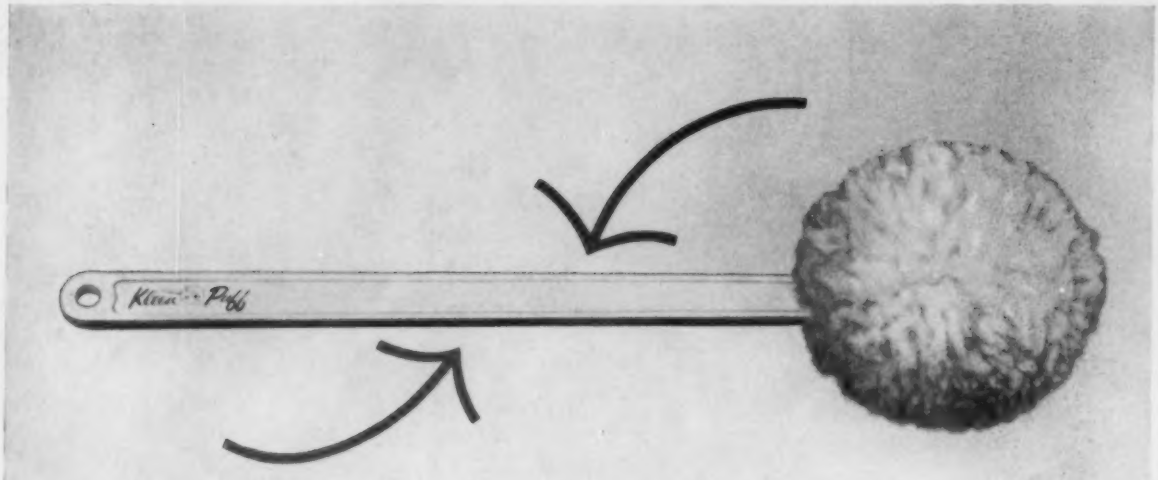
Business machine manufacturers will find M&T spray-on vinyls very well suited to their products. Not just for decorative texture and eye-appeal, but for long-term *durability*, too. There is hardly a finish that so economically offers so much resistance to scratching, scuffing, abrasion—and the encroachment of "age."

Write for more information on what M&T Vinyl Finishes can do for your products.

M&T COATINGS & FINISHES

METAL & THERMIT CORPORATION
General Offices: Rahway, New Jersey
In Canada: M&T Products of Canada Ltd., Rexdale, Ont.

For more information, turn to Reader Service card, circle No. 361



CMPC-molded mop handle has built-in germ fighter

Often, engineered plastics add important extra sales features to a product. A good example is the "Kleen-Puff"® mop, manufactured and sold internationally by the Zelinkoff Company of Wichita, Kansas.

CMPC injection molds the one-piece handle using a polypropylene-bacteriostat mixture. The bacteriostat, Biozel®, inhibits the growth of bacteria and odor-causing germs and resists mildew and mold . . . a big selling plus with housewives. Biozel is non-toxic and non-irritating to the skin. Tests indicate that its effectiveness continues for a year and longer.

Polypropylene was selected for the handle because of its strength, light weight and flexibility. These properties enabled CMPC to mold a small strap, used to fasten the mop attachment, as an integral part. Thus, the handle is strong and flexible—will bend around curves without breaking and it has no sharp edges to scratch surfaces being cleaned.

Perhaps these same advantages can be applied to your product. A call to your Chicago Molded Sales Engineer will bring you the services of an experienced and trained plastics specialist. Or write:

Send for new brochure "Design and Purchase of Custom Molded Plastics."

CMPC

CHICAGO MOLDED PRODUCTS CORPORATION
1020 F North Kolmar Avenue
Chicago 51, Illinois

For more information, turn to Reader Service card, circle No. 414

For more information, circle No. 417

The New Low-Viscosity Modified Epoxy

Lower in cost, too, than other modified epoxies, lower vapor pressure, less irritating to the skin, pleasant odor, and producing higher flex strengths when cured, CIBA Araldite® DP-310 Epoxy Resin is the result of years of special research at CIBA laboratories. Modification with a highly effective reactive diluent is accomplished during manufacture.

End uses? You name them! Adhesives, laminating, flooring, tooling, electrical, sealants . . . wherever low viscosity and low vapor pressure for maximum impregnation or filler loading is a must.

The price is the same as for an unmodified resin. You will want full particulars.

CIBA Araldite DP-310

C I B A

CIBA Products Corporation
Fair Lawn, New Jersey

CIBA
First in Epoxies

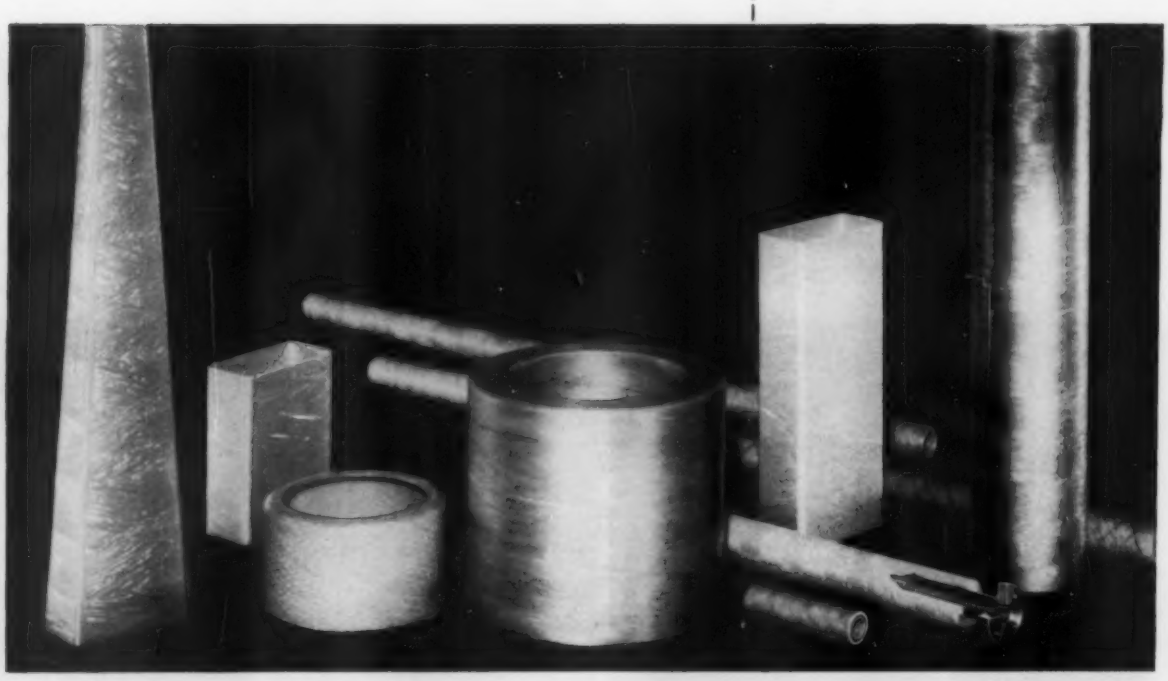
SPAULDING GFW-60*

*Glass filament wound epoxy tubing gives industry a new high burst strength material

Spaulding GFW-60 is designed to provide industry with a material of extremely high burst strengths for such applications as circuit breaker arc interruption chambers, high-voltage fuse tubes, switch gear and similar type components. It can be furnished with fibre liners, metal inserts, or with conductive layers.

Its ratio of burst strength to axial tensile strength can be varied to fit specific applications.

It is available in a variety of circular sizes and lengths, and with special shapes.



PROFILE OF CHARACTERISTICS

SPAULDING GFW-60 (1" x 1¼" size)		
Water Absorption	%	.05
Grease Burst	psi	22,500
Tensile Strength	psi	8,250
Compression Strength Axially Radially	psi As Received As Received	 19,300 920
Dielectric Strength V/M Perpendicular	Short Time	401+

As with All of its Products for Industry, Spaulding Offers Complete Value Analysis and Fabricating Services for Your Application of GFW-60. Contact Spaulding for Details.

SPAULDING FIBRE COMPANY, INC.

321 WHEELER STREET, TONAWANDA, NEW YORK

For more information, turn to Reader Service card, circle No. 375

Titan® RC Hex

T.M.

Titan's new *RC Hex* is free-cutting brass hexagon rod with radius corners.

It offers exciting new advantages when used on screw machines. It is best for making bolts, nuts, hydraulic and automotive fittings, and other parts where the hex serves as a wrenching shape. Here's why:

Superior Points of *RC Hex* Brass Rod

- Weight-per-foot saving averages ½% over conventional sharp-cornered hex rod. Costs are less.
- Screw machines can take larger rod because of reduced dimension across Titan *RC Hex* rod corners.
- Screw machine operations are quieter and safer because sharp hex corners are rounded.
- Stock tube liners last longer. Machine downtime is reduced because of "rounded" hex bars. "Corner" damage is less. Higher speeds can be used.
- Parts made of Titan *RC Hex* take superior plating because of reduced buildup on corners. Finishing costs less.
- *RC Hex* facilitates assembly of finished parts.
- "Rounded" machined hex pieces don't nick or burr during handling and shipping.
- Finished products made from Titan *RC Hex* have improved "rounded" quality look... added to the natural beauty and strength of being brass.

Titan produces *RC Hex* rods in many sizes. Most are from ½" to 2½" across flats. "Special" die sizes are standard at Titan. Let us know your needs.

Consult Mill for *RC Hex* in alloys in addition to Free-Cutting Brass.

Order Titan *RC Hex* from your nearest Titan Man. Rapid shipments are made to you direct from four Titan brass rod mill depots: Bellefonte, Pa.; Seymour, Conn.; Indianapolis, Ind.; Newark, Calif.

Established 1915

Write for RC Hex *die size list and catalog data*

Chrome-plated brass parts machined from Titan RC Hex. Reduced buildup on corners gives superior plating results.

TITAN® METAL MANUFACTURING COMPANY

DIVISION OF **CERRO CORPORATION**

Bellefonte, Pa. • Newark, Calif. • Offices & Agencies in Principal Cities

RODS • FORGINGS • DIE CASTINGS • WELDING RODS • WIRE

For more information, turn to Reader Service card, circle No. 330

B.F.Goodrich

PLASTICS FOR LIVING

There is one mark of similarity shared by all the members of the family of plastics from B.F.Goodrich Chemical. The reputation built by this plastic material producer for unusually high uniformity and reliability is valued in the operation of every user of a BFG Chemical material.

More than twenty years of experience in maintaining an exceptional reputation for assistance to customers is at your disposal when you choose to profit with any of these plastic materials. For more information, write Department NN-4, B.F.Goodrich Chemical Company, 3135 Euclid Avenue, Cleveland 15, Ohio. In Canada: Kitchener, Ontario.

AbSON™

You've never seen an ABS material so easy to mold! Here's how to get all the advantages ABS materials give a product, yet get easier processing, too. Use Abson! It provides excellent impact resistance, resistance to corrosion and chemicals, as well as fine surface finishes and detail.

Yet the superior flow characteristics provide advantages in moldability and vacuum-forming ability (in standard equipment) that no other ABS material can offer. You can reduce operating temperatures, providing a solution to color drift. Cycle times can be shortened, and gauge pressures can be reduced.

There's a lot more to the advantages you can get by using Abson. For complete information, write today.

ESTANE®

This urethane is the first thermoplastic elastomer! Estane gives you two significant processing advantages: it is an elastomer requiring no curing and it is thermoplastic. You can recycle indefinitely. Products are tough, unusually resistant to cut and tear, and resistant to ozone, fuels and oils.

Otherwise wasted stock accumulated through normal fabrication can be recycled when you use Estane. You can extrude, injection-mold, mill, calender and dissolve without cross-linking or curing. Processing is much like vinyl—as fast, on the same equipment, with similar settings. Yet many physical properties are like those of rubber.

To get complete information about using Estane, write for Bulletin 18.

GEON®

Look how many ways this versatile plastic performs! As a soft, flexible material, Geon vinyl provides an excellent combination of properties, either by itself or in combination with other materials. Geon provides inertness or resistance to chemical attack, acids, alcohols, oils and solvents—as well as providing superior electrical properties, and resistance to abrasion and weathering. Extruded, molded or used as a coating on metal, wood, paper or other materials, Geon offers outstanding opportunity to create new products or improve old ones.

In rigid form, Geon provides the same basic properties, with structural advantages added. For example, rigid Geon is used in many building applications—as sash, moldings, coving, or decorative sheet. Rigid Geon pipe and conduit provide corrosion-resistant advantages resulting in far longer, trouble-free life. Rigid Geon extrusions are also valued for their spring-back properties and the fact that extrusions can be made which offer weight-carrying potential.

New hi-temp Geon offers the advantages of Geon vinyl for applications withstanding operating temperatures of 215°F; 60°F higher than previous rigid vinyls could withstand. This new addition to the Geon vinyl family can be used in the same way as any of the other uses of Geon—for flexible or rigid applications, sheet, moldings, extrusions.

Complete information telling about the many ways Geon can help improve a product or open whole new markets is readily available. Write for it today.

B.F.Goodrich Chemical

a division of The B.F.Goodrich Company

For more information, turn to Reader Service card, circle No. 353

Textolite®/reliability

COMPARE NEW Textolite® G-5, 11588

	Water Absorption (% 24 hr. @ 25C)	Flexural Strength (lbs./sq. in.)		Impact Strength (ft. lb./in. notch)	Arc Resistance (seconds)	Dielectric Strength parallel to laminate D-336/50 (KV/in.)	Approx. Price $/lb.
		Cond. A	E-200/150				
Glass/Melamine MIL-P-15037 (GMG) requirements	2.7	50,000	⟨ 30,000*	13	180	⟨ 5*	$2.50
Glass/Melamine MIL-P-15037 (GME) requirements	0.8	60,000	30,000	7	180	50	$2.50
Glass/Melamine Textolite® 11588 (typical values)	0.25	48,000	45,000	16	183	60	$2.50
Glass/Polyester GPO-1 (Typical Industry Values)	1.0	23,900	10,750*	8	100	19*	$1.00
Glass/Epoxy G-10 (Typical Industry Value)	0.35	63,200	5,050*	9	60	30*	$3.10
Glass/Silicone G-7 (Typical Industry Values)	0.35	30,000	18,000*	6.5	185	16*	$6.50

*Test values not required by specifications

HOW MANY NEW APPLICATIONS can you suggest ?

A look at the chart above and you will see that here is a unique glass/melamine laminate with excellent moisture resistance and flexural strength. In addition, 11588 has good impact and dielectric strength, as well as being highly arc resistant. If you have applications that have required epoxy-based laminates, for example, see if this glass/melamine might not be suitable, at lower cost.

Designed primarily for use by electrical apparatus and appliance manufacturers, 11588's unusual combination of properties makes it highly attractive as an insulator for a multitude of electrical and electronic application. The relatively low cost per pound plus its outstanding characteristics, make this laminate ideal for use as slot wedges, terminal boards, transformer spacer blocks and . . . well, you name it.

You may be using any one of the materials above for a particular property it possesses. If so, look closely at G-E Textolite G-5 11588. It may have the property you need plus **additional** desirable properties. Many applications certainly must demand such favorable combinations — what can you do with these properties? We will be happy to work with you or send complete information and samples. Write: Laminated Products Department, Section MD-61, General Electric Company, Coshocton, Ohio.

Progress Is Our Most Important Product

GENERAL ELECTRIC

For more information, turn to Reader Service card, circle No. 425

die cast appliance part
North Amer. Philips nylon coil form
Dictaphone die cast circuit connector
Westinghouse insert molded insulating screw
tuner part
instrument gear
Bunsen die cast lighter part
die cast power tool part
Samsonite Intercast hinged luggage closure
GM acetate car radio part
flashlight part
Argus die cast camera part
Yale & Towne die cast lock part
Western Electric Delrin phone dial part
how many
of these
25 GRC
small parts ideas
can you use
in your business?
General Electric die cast timer part
Lionel die cast model train part
Remington Rand insert cast sensing brush
die cast mechanical pencil part
control parts
IBM insert cast-mold commutator brush
Detecto die cast scale part
nylon adding machine part
Minneapolis-Honeywell die cast switch part
Ford Motor die cast horn part

Parts shown ⅔ actual size

Section of our tool shop, where quality starts for GRC TINY ZINC ALLOY DIE CASTINGS and ENGINEERING THERMOPLASTIC MOLDINGS

They are, truly, Shapes of Progress...tiny components that mark Gries' significant and recognized strides in die casting and molding small parts. Each makes a better, more profitable product possible. Yet none could have been made with such high quality...so economically...without GRC's specialized capability: the combination of design experience and unique automated facilities.

NO SIZE TOO SMALL!
Maximum sizes up to 2", ½ oz.

What about your idea...your product? GRC gives you design flexibility you may never have thought possible...precision and savings thru 25 years of die casting and molding tiny parts exclusively. *No size is too small...no design too intricate to consider.*

We welcome your inquiries...and offer several significant booklets to help expand your design horizons. Won't you write?

Twenty-five Years of Progress in Tiny Parts Design and Production.

GRIES REPRODUCER CORP. GRIES GRC®

WORLD'S FOREMOST PRODUCER OF SMALL DIE CASTINGS
153 BEECHWOOD AVE., NEW ROCHELLE, N.Y.
NEW ROCHELLE 3-8600

See us at Plastics Show #1549

For more information, turn to Reader Service card, circle No. 379

BOND FAILURES CAN BE PREVENTED!

Here's how to stop 13 of them...

Type of Failure	Solution
THERMOSETTING ADHESIVES	
• Cohesive failure	Check film with solvent used in adhesive. If solvent softens the adhesive film or becomes tacky, this indicates insufficient cure. Make sure bond line time and temperature is used.
• Adhesive failure from metal	If metal surface has a white, clean appearance, check cleaning technique.
• Adhesive failure from substrate other than metal	Try prime coat of diluted adhesive, also check compatibility.
• Cellular areas in adhesive line	Increase pressure and/or adhesive.
CONTACT ADHESIVES— room temperature setting	
• Tacky film	If film should dry hard but remains tacky, the cause may be entrapped solvent or migration of plasticizer from one substrate.
• Shiny areas	Poor contact, insufficient pressure or insufficient amount of cement.
• No bond	If heat reactivated type, adhesive was too cool at time of assembly or poor compatibility.
• Failure in adhesive from metal	Improper cleaning.
• Failure from substrate other than metal	Incompatible or unclean surfaces.
HOT MELT	
• No bond	Incompatibility, adhesive too cool at time of assembly. Parts too cool at time of application of adhesive.
EPOXY BASE ADHESIVES AND CASTING COMPOUNDS	
• High exotherm	Mix lower volume and pour mixed material into shallow tray. Cool base and activator before mixing or use Metermixing equipment.
• Tacky film or casting	Improper base activator ratio, improper mixing of base and activator, improper cure. Check bond line temperature.
• Flexible casting or film of rigid adhesive or casting compound	Improper mixing of base and activator, improper base and activator, improper cure. Check bond line temperature.

Bond failures can be prevented! Raybestos-Manhattan's adhesive experts also have solutions to less common causes of bond failures . . . based on more than 20 years' experience in the production of bonded assemblies and the manufacture of adhesives, coatings and sealers. Why not call on them today for the answers to your adhesive problems—no cost or obligation, naturally.

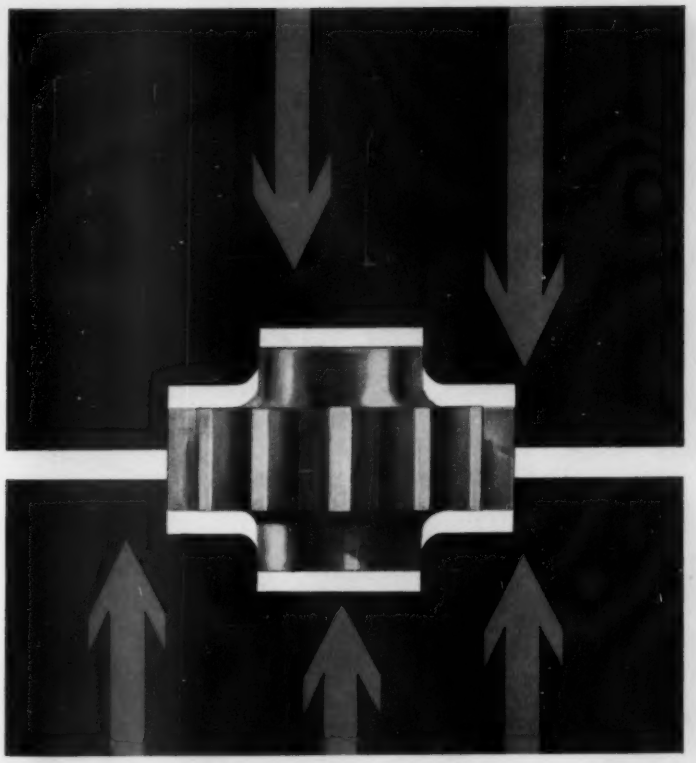
R/M Bulletin No. 700 is packed with helpful technical information on Ray-BOND adhesives. Write for your free copy now.

RAYBESTOS-MANHATTAN, INC.

ADHESIVES DEPARTMENT, Bridgeport, Conn. • Chicago 31 • Detroit 2 • Cleveland 16 • Los Angeles 58

R M

For more information, turn to Reader Service card, circle No. 427



most flexible

powder metal press

available!

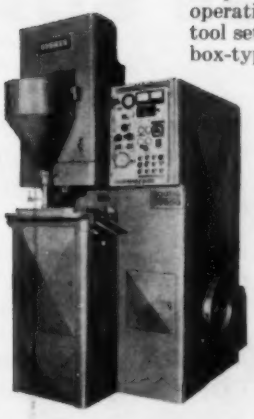
STOKES BUILT-IN PRESS MOTIONS

trim costs of powder metal parts

This 50-ton Stokes press gives you the multiple motions you must have for complex powder metal compacting . . . *without the expense and delay of manufacturing* and setting up complex tooling for *every job.* Stokes built-in motions give highest production of even the most complicated parts.

The Model 640 Powder Metal Press provides two upper and three lower compacting motions with underfill or resistance pressing controls. By simply positioning a selector switch and sequence dials at the control panel, the third lower motion can be set up as a resistance motion, a third lower punch, or as a stationary, movable, or ejecting core rod.

All press motions are precisely indicated and controlled from the central operating position in front of the press. Single cycle control simplifies tool set-up and facilitates compacting of parts with inserts. Rigid cast box-type frame overcomes deflections common in gap frame presses. Yet it provides accessibility for tool changing not available in four post presses.

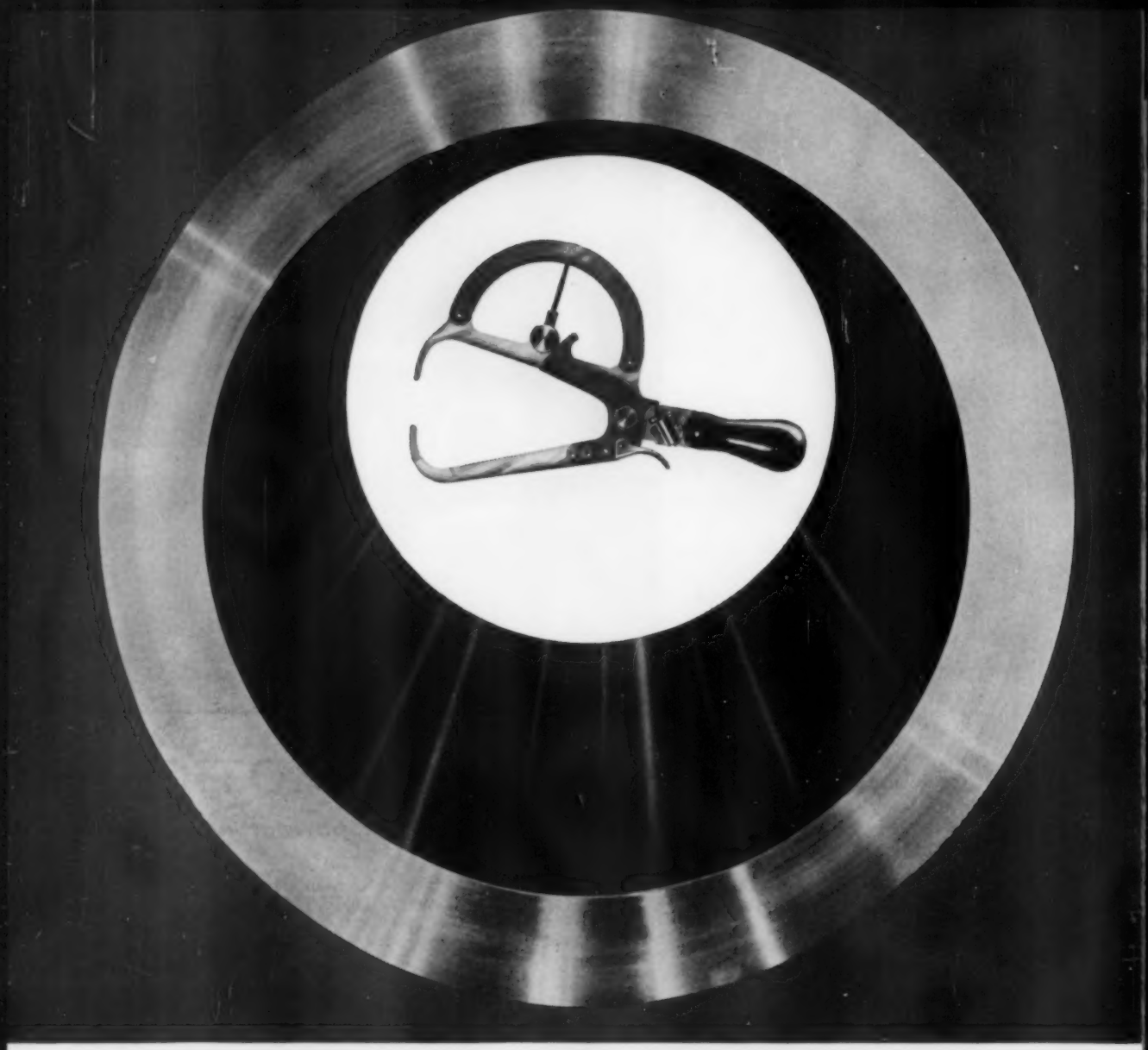


For complete technical data on Stokes Model 640 50-Ton Multiple-Motion Powder Metal Press, write for Bulletin No. 1200. For any compacting or pressing job, no matter what the material, no matter what the size or production requirements . . . you can do it faster and more economically with Stokes equipment. Consult Stokes Engineering Advisory Service for complete technical assistance in designing parts, punches and dies, or complete production facilities.

STOKES

POWDER METAL PRESS DIVISION • **F. J. STOKES CORPORATION** • 5500 TABOR ROAD, PHILADELPHIA 20, PA.

For more information, turn to Reader Service card, circle No. 320



NEW SIZE RANGE SURPRISE!

HERE'S A NEW PROCESS in centrifugally spun tubing that offers you greater freedom in design. It's ACIPCO CERAM-SPUN® . . . the new ceramic mold process* that is not limited by equipment sizes!

NOW, YOU CAN ORDER almost any combination of sizes you require. ACIPCO CERAM-SPUN® tubes offer O.D.'s from 2.25" to 50"; and wall thicknesses from .25" to 8". As-cast lengths are furnished from 4 feet to 20 feet, longer lengths are made by welding.

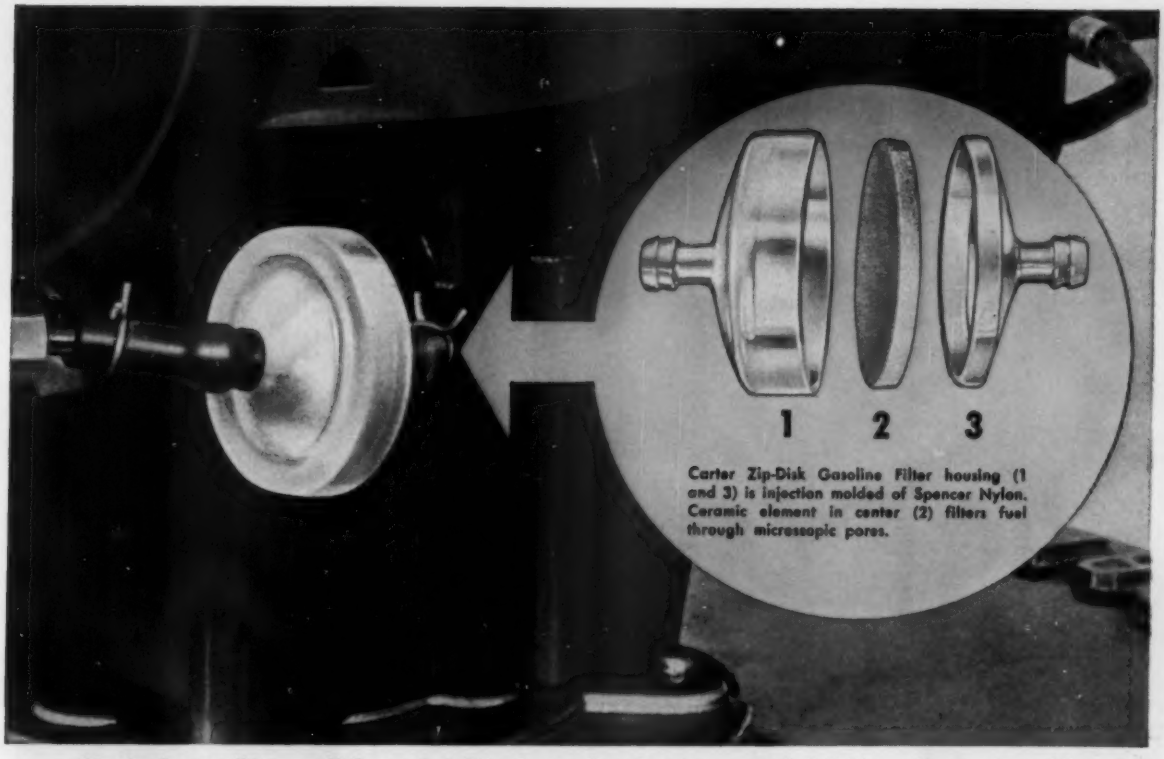
THINK OF HOW MUCH this process can save you! You'll avoid the cost of unnecessary metal waste, and excessive machining charges. And ACIPCO's complete "under one roof" operations — including heat treating, machining and welding — offer many additional economies. No need for the delays and excessive costs that often result in buying from multiple sources.

If you design, manufacture or use tubular component parts, it will certainly pay you to investigate the versatility of ACIPCO CERAM-SPUN® tubing and the flexibility of ACIPCO's integrated facilities. Contact **ACIPCO STEEL PRODUCTS,** Division of American Cast Iron Pipe Company, Birmingham 2, Alabama.

*Patent applied for

ACIPCO CERAM-SPUN®
STEEL TUBING

For more information, circle No. 400


1 2 3
Carter Zip-Disk Gasoline Filter housing (1 and 3) is injection molded of Spencer Nylon. Ceramic element in center (2) filters fuel through microscopic pores.

This simple, install-it-yourself Carter fuel filter traps impurities that can cause flooding, stalling and gas waste. Engineered especially for power mowers, outboard motors and other light gasoline engines, this super-efficient filter provides easier starting, cuts maintenance costs and reduces the need for overhaul.

How Carter Carburetor Builds A Better Fuel Filter With Spencer Nylon:

As a leader in its field, Carter Carburetor Division of ACF Industries was among the first to recognize the many benefits of using nylon for automotive engine accessories. In designing their Zip-Disk Gasoline Filter, Carter production experts utilized a Spencer Nylon housing custom-molded by Danielson Manufacturing Company. Here are some of the advantages they achieved:

1 Economy: Molding the parts of Spencer Nylon eliminates expensive stamping or machining processes normally required by metals. There is no need for protective or decorative plating, polishing or painting. Assembly is also simplified because screwing, threading and welding are unnecessary.

2 Durability: In addition to its high impact strength, the Spencer Nylon housing is unaffected by gasoline and is not subject to corrosion from moisture. Motor vibrations and high engine temperatures will not distort its shape or cause cracking.

3 Visibility: The transparent Spencer Nylon housing permits the user to check the filter for contaminants without disassembling a single part.

4 Light Weight: Weighing less than an ounce, the Spencer Nylon housing can be attached with snap-on connections; without heavy-duty clamps, or additional braces to prevent vibration noises.

How about your product — can it be made better for less with Spencer Nylon? It's well worth considering. Investigating the possibilities costs you nothing. Just contact Spencer at the address below.

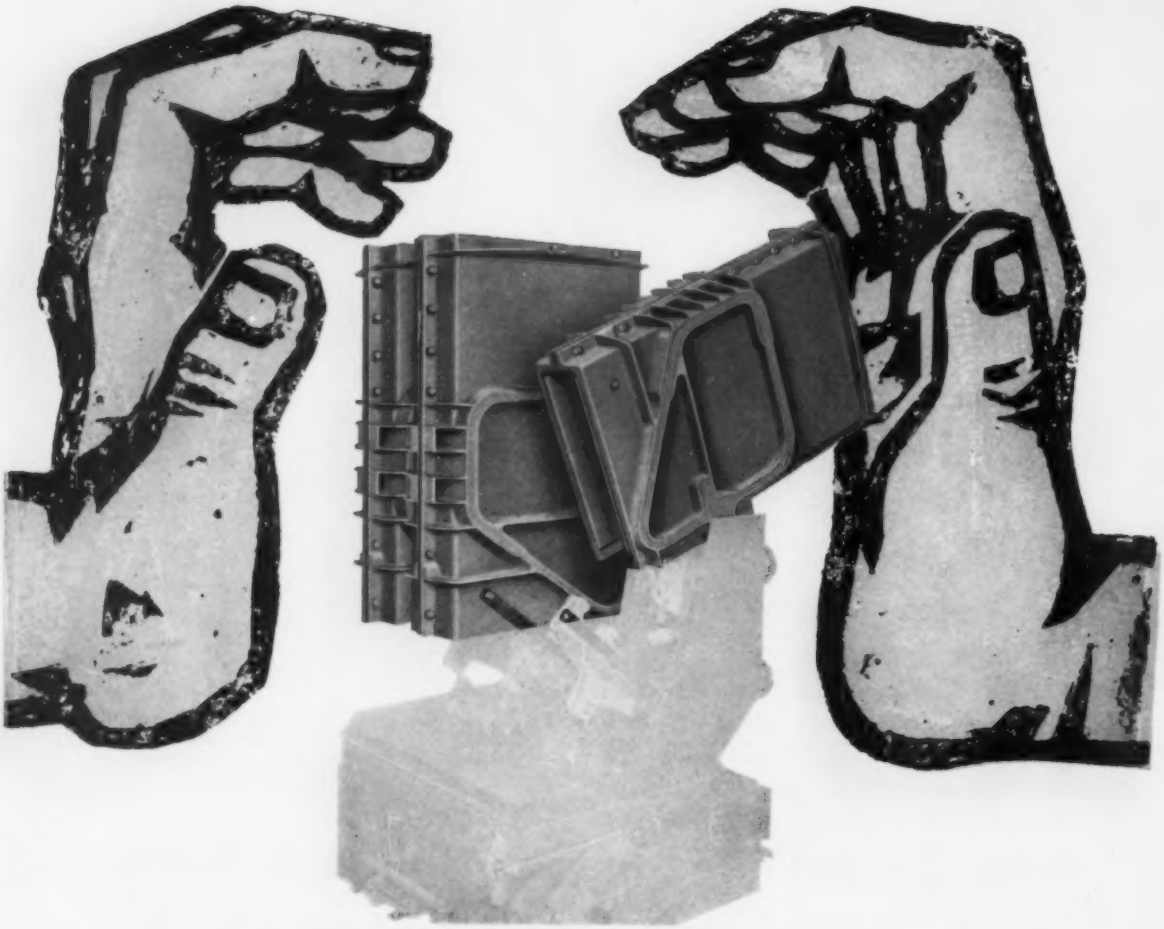
SPENCER®

SPENCER NYLON

SPENCER CHEMICAL COMPANY

Dwight Building . . . Kansas City 5, Missouri

For more information, turn to Reader Service card, circle No. 444



How to squeeze compact switchgear into still less space!

Throughout the electrical industry, they're talking about St. Regis® Panelyte's revolutionary new arc chute for I-T-E's latest switchgear. For, among other advantages, this chute helps make the switchgear approximately one-third smaller than the next most compact unit made.

Each chute is molded at 2,000 psi using a non-tracking, flame-retardant polyester-glass fiber molding compound. Molds are 24" x 15" x 2¼" and must meet a minimum dielectric strength test of 250 volts/mil.

Special test molds—A *joint* Panelyte I-T-E development program was underway long before the first drawing. Panelyte engineers made special test molds to determine the optimum wall configuration for housing the chute's blowout coils. Then Panelyte engineers worked hand-in-hand with I-T-E to cut both overall chute size and unit cost.

Extensive Panelyte manufacturing facilities—When the switchgear's design was frozen, Panelyte's manufacturing group took over. Using special presses, quality production was both fast and economical. Each molding was proof-tested to assure highest quality.

Why don't you take advantage of Panelyte's Customer-Supplier Development Program . . . and of Panelyte's 22 years' experience in high-pressure molding? For complete details on *all* the advantages Panelyte offers you, write today to Dept. MDE-661, Industrial Panelyte Division, St. Regis Paper Company, No. Enterprise Ave., Trenton, N. J.

St.Regis PANELYTE®

Panelyte also produces laminated plastic sheets, rods, tubes and copper-clad stock, as well as special laminates and fabricated parts.

For more information, turn to Reader Service card, circle No. 380

START: Heated billet is centered between dies of the Slick Mill.

15 SECONDS
Upset-forging starts.

30 SECONDS
Rolling cycle starts.

40 SECONDS
Forging is completed.

55 SECONDS
Forging is removed from mill.

One minute... one circular forging

That's all the time it takes to convert a heated billet (100 to 2,000 lb) into a contoured forging on Bethlehem's unique Slick Mill.

But fast operation is only one reason why Bethlehem's Slick Mill turns out a top-quality forging at a price that's hard to match.

Ask us, or our nearest sales office, about the quick die changes, which make it possible—and economical—to set up production runs as small as 25 or 50 pieces. Ask about the low die charges which are made possible by the brief contact between die and work. Ask about the light-weight sections this mill can produce, without sacrificing strength.

We'd also like to tell you about the excellent grain flow, machinability, and soundness of every Bethlehem circular forging.

Ask. You'll like the money-saving answers.

Steel *for Strength ... Economy ...Versatility*

BETHLEHEM STEEL COMPANY, Bethlehem, Pa.
Export Sales: Bethlehem Steel Export Corporation

BETHLEHEM STEEL

BETHLEHEM STEEL

For more information, turn to Reader Service card, circle No. 389

Tempilaq° temperature indicating coatings

■ **Tempilaq°** consists of materials of calibrated melting points suspended in an inert, volatile, nonflammable vehicle. It lends itself more readily than Tempilstick° temperature indicating crayons for use on glass or other polished surfaces.

The manuals and data sheets of a number of leading manufacturers in the electronic field suggest Tempilaq° as a convenient means of determining operating temperature characteristics of components.

Some of the applications for which Tempilaq° has been found very useful are—

- Monitoring metal-to-glass seal temperature of electronic tubes.
- Safeguarding television camera tubes against overheating.
- Checking baking temperature of television picture tube bulbs.
- Studying temperature rise of transmitter tubes.
- Pinpointing component failure due to overheating.
- Signaling temperature rise of rheostats.
- Determining operating temperatures of industrial x-ray machines.
- Determining overloaded power switches and other electrical apparatus.

These are only a few of the typical uses but they may suggest how Tempilaq° may help you solve your problem. Write to us—our experience in this field is at your disposal.

THE KEY TO *Tempilaq°* DEPENDABILITY

1. INSTANTANEOUS INDICATION—The response delay of a thin layer of Tempilaq° is of the order of a millisecond.
2. ACCURACY—Within one per cent of the stated temperature rating in each instance—usually well within that tolerance.
3. TIME-INDEPENDENCE—The indication of Tempilaq° does not depend on the duration of heating.
4. EASE OF INTERPRETATION—The melting of a Tempilaq° coating is sharp and unmistakable—provides definite "yes" or "no" information regarding attained temperature—leaves no room for doubt.
5. NON-REVERSION—A melted Tempilaq° coating, on cooling, does not revert to its original dull-opaque appearance but remains glossy-transparent—makes subsequent interpretation a simple matter.

Each batch of Tempilaq° is carefully calibrated for melting point by our own laboratory and independently checked for accuracy by a distinguished firm of consulting chemists.

© TEMPIL° CORPORATION, 1961

AVAILABLE IN 2 EASY TO USE FORMS!

Tempilaq° that you can spray on is available in some forty systematically spaced temperature ratings covering the range from 100°F to 650°F, inclusive. Development work is under way to perfect aerosol packaging on the forty higher ratings of Tempilaq° spanning the range from 700°F to 2500°F, which are presently available in the standard glass bottle packaging only.

Tempilaq° in aerosol packaging is presently available in the following temperature ratings: (in °F)

100	200	275	313	350	425	500
138	213	282	319	363	438	525
150	225	288	325	375	450	550
163	238	294	331	388	463	575
175	250	300	338	400	475	600
188	263	306	344	413	488	650

Aerosol packaged Tempilaq° (8-oz. can) containing 4 oz. of Tempilaq° plus required propellant **$5.00 ea.**

Tempilaq° that you brush on is available across the full range—from 100°F to 2500°—in eighty-one carefully calibrated temperature ratings. Like Tempilaq° in the aerosol package, each indicates its stated temperature with an accuracy of plus or minus 1%.

Tempilaq° in bottles is available in the following temperature ratings: (in °F)

100	213	300	363	475	750	1050	1450	1850
113	225	306	375	488	800	1100	1480	1900
125	238	313	388	500	850	1150	1500	1950
138	250	319	400	525	900	1200	1550	2000
150	263	325	413	550	932	1250	1600	2100
163	275	331	425	575	950	1300	1650	2200
175	282	338	438	600	977	1350	1700	2300
188	288	344	450	650	1000	1400	1750	2400
200	294	350	463	700	1022	1425	1800	2500

Tempilaq° in bottles is available in 2-oz. size at **$2.00 ea.** and pint-sized units at **$12.00 ea.**

Sorry—but we cannot undertake to supply free samples. You can, however, make a trial purchase of Tempilaq° in either the standard 2-oz bottle or an aerosol container. If, for any reason Tempilaq° proves unsuitable for the application you have in mind, the full purchase price will be refunded.

Tempil° CORPORATION 132 WEST 22nd STREET, NEW YORK 11, N.Y.

For more information, turn to Reader Service card, circle No. 368

For more information, circle No. 418 ➤

Why men with ideas are using new, versatile VITEL resins

Packed with potential to pay out ideas—aptly describes the exciting new family of VITEL polyester resins. In appropriate solutions, these resins give metal a tough, weather-resistant coating. They add a rich tone to wood; give paper a high gloss; provide lasting bonds in laminates; serve ideally as a binder in printing inks—even on slick surfaces such as vinyl.

More ways new VITEL resins shine? Their glasslike clarity makes a finish a thing of beauty. Their unusual adhesion makes them applicable to a wide range of surfaces and products. Their excellent electrical properties answer many insulating problems. Their chemical resistance is outstanding.

Another extra: VITEL resins are so workable they can be applied by brushing, spraying, roll coating, dipping —all with conventional equipment.

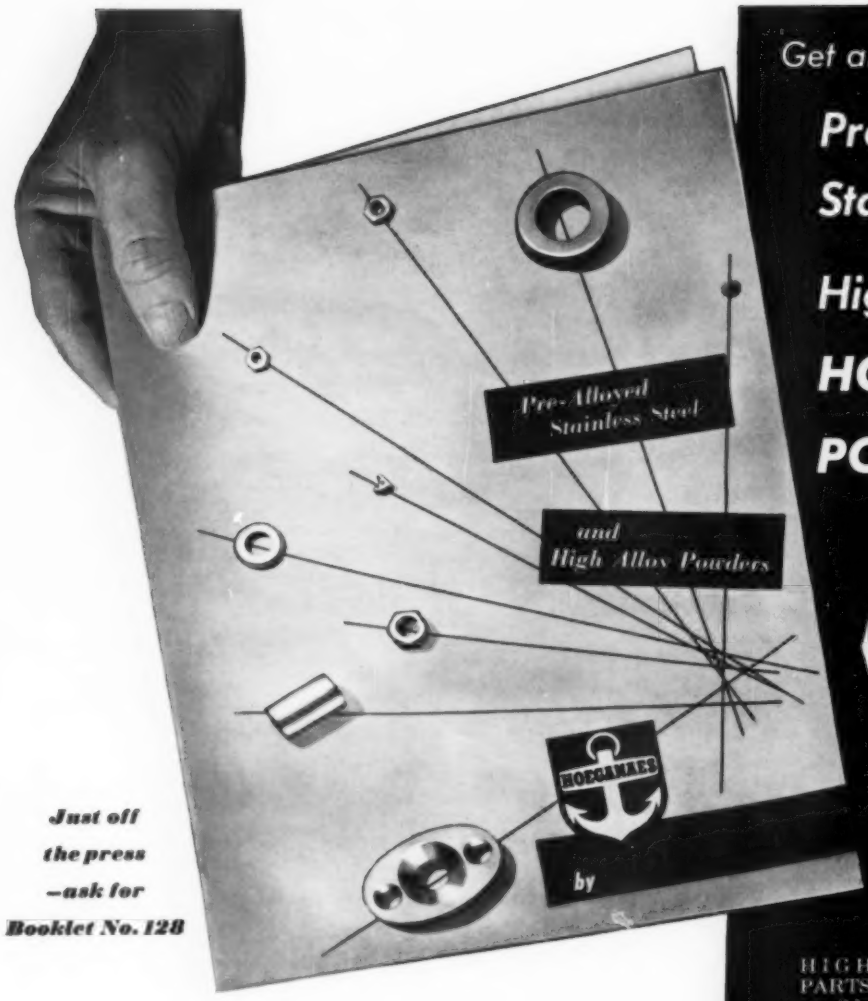
New highs in appearance, performance and sales are yours with VITEL solution resins. For technical data plus resin samples, write Goodyear, Chemical Division, Dept. F-9437, Akron 16, Ohio.

Lots of good things come from

GOODYEAR

CHEMICAL DIVISION

Vitel, a Polyester resin—T. M. The Goodyear Tire & Rubber Company, Akron, Ohio



Get all the facts about

Pre-Alloyed Stainless Steel and High Alloy HOEGANAES POWDERS

. . . they're all here

in this new,

just-off-the-press

HOEGANAES
BOOKLET NO. 128

Just off the press —ask for Booklet No. 128

HIGH ALLOY METAL PARTS FABRICATION is now possible on a low cost production basis thanks to the excellent physicial properties of Hoeganaes High Alloy and Stainless Steel Powders.

Then, too, our research and field engineering staff are available to work with you on your individual requirements . . . with a practical solution in mind. They're as near as your 'phone. Start now by requesting your free copy of booklet No. 128 . . . a copy will be in the return mail.

Here's more helpful free data . . . .
HSIC Research Report on 316L Stainless Powder

A 2-page research report on Hoeganaes 316L Stainless Powder; developed to help guide you on the proper processing of this field-tested Stainless Powder.

Graphs show the physical properties you can expect from HSIC 316L under the conditions covered by this report.

Write for your copy today—ask for HSIC Research Report No. 5. A copy will be in the return mail.

HSIC

HOEGANAES

HOEGANAES SPONGE IRON CORPORATION

RIVERTON, NEW JERSEY

SALES REPRESENTATIVES IN PRINCIPAL CITIES: Birmingham, Chicago, Cincinnati, Cleveland (Fostoria), Edmonton (Alberta, Canada), Montreal (Canada), Toronto (Canada), Los Angeles, Mexico 16, D. F. (Mexico), Minneapolis, New England (Elmira, N. Y.), Odessa (Texas), Philadelphia (Riverton, N. J.), Pittsburgh, San Francisco, St. Louis

For more information, turn to Reader Service card, circle No. 403

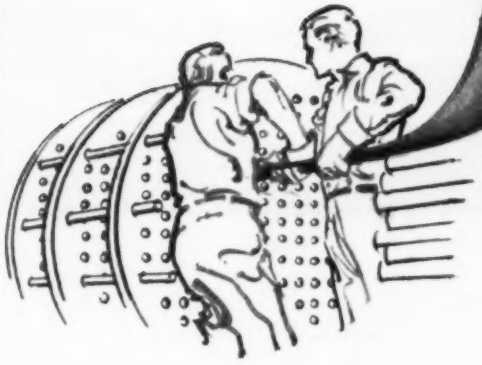
For more information, circle No. 419 ➤

0.001″ CORROSION

IN 1250 YEARS

WITH TITANIUM

HEAT EXCHANGER TUBE



ARE YOU BUYING TUBE BY THE YEAR?

If a shortage of fresh water for heat transfer operations is causing your company to use sea water or brackish waters for heat removal duty, here are some mighty important facts for your consideration:

(1) In salt water service, the corrosion rate of commercially pure titanium tubing has been calculated at 0.001″ in 1250 years. In addition, tubing manufactured from titanium is immune to stress corrosion cracking in this type of service. Tests also indicate no apparent tendency toward crevice corrosion nor is there any indication of pitting from marine growth deposits.

(2) On the other hand, the tendency of some ferrous and nonferrous metals toward corrosion cracking and pitting with corrosive elements on the tube side and sea or brackish water on the shell side makes frequent maintenance and material replacement a costly procedure . . . TITANIUM ELIMINATES THIS COMPLETELY.

(3) Because of its resistance to corrosion in this type of service, thin walled titanium tubing can be specified as can thinner sections for other components. The result is greater heat transfer efficiency and, because of greatly increased operating life, a lower prorated cost per foot for titanium heat exchanger tube . . . the tubing that gives *years* of service instead of only *months*.

This is but one of a number of areas where Wolverine titanium heat exchanger tube can bring increased heat transfer efficiency at lower costs. Why not have Wolverine Tube's Field Engineering Service staff analyze your heat transfer operations? All you have to do is fill in and mail the data sheet on the reverse side of this page. There is no obligation. Do it today!

WOLVERINE TUBE

DIVISION OF

Calumet & Hecla, Inc.

DEPT. N, 17258 SOUTHFIELD RD., ALLEN PARK, MICH.

TUBEMANSHIP in Copper—Copper Alloys—Aluminum—Special Metals

PLANTS IN DETROIT, MICH. AND DECATUR, ALA.
SALES OFFICES IN PRINCIPAL CITIES

TITANIUM COMPARISON CHECK SHEET

WOLVERINE TUBE
17258 Southfield Road
Allen Park, Michigan

GENTLEMEN:

We are interested in the possibility of using titanium heat exchanger tubing in our heat transfer operations. Will you please have your Heat Transfer Specialists analyze the following technical data and advise us if Wolverine titanium heat exchanger tube would be practical under the following conditions?

PLEASE ANSWER ALL QUESTIONS AS COMPLETELY AS POSSIBLE

1 **What is O.D. of material?** **Wall Size?** **Quantity?** **Alloy?**

2 **Describe corrosive product with percent of concentration.**

3 What is maximum temperature of corrosive product?

4 What is tube side operating pressure?

5 Is environment oxidizing or reducing?

6 What is present tube life?

▲ TEAR OUT HERE

FILL IN AND MAIL

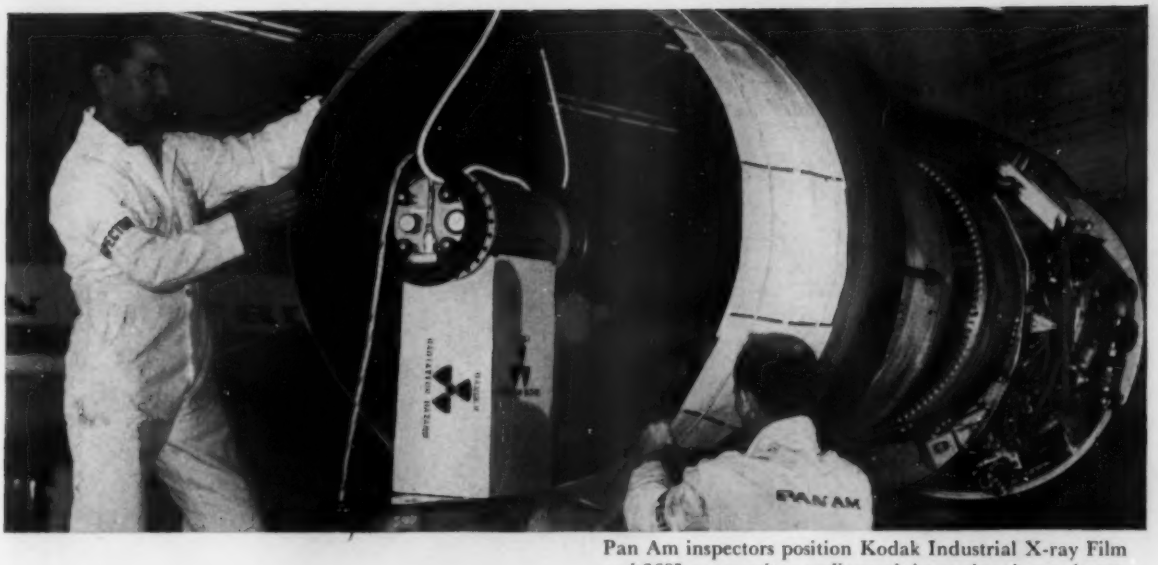
WOLVERINE TUBE
DIVISION OF
Calumet & Hecla, Inc.
DEPT. N, 17258 SOUTHFIELD RD., ALLEN PARK, MICH.
TUBEMANSHIP in Copper—Copper Alloys—Aluminum—Special Metals

NAME _____ TITLE _____

COMPANY _____

ADDRESS _____

CITY _____ ZONE _____ STATE _____



Pan Am inspectors position Kodak Industrial X-ray Film and 360° x-ray unit to radiograph jet engine thrust ejector.

It throttles the roar of a 16,000-lb. thrust

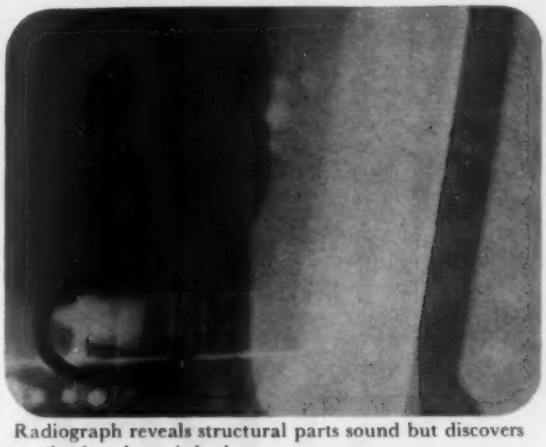
Thrust ejectors on jet engines must be examined every 400 hours. Pan American Airways does it radiographically—cuts inspection time more than 90%.

To remove the floating skin on a jet thrust ejector and check its insides takes a lot of expensive man-hours. But Pan Am gets the answer—now—in one-tenth the time.

By wrapping both Type AA and Type M Kodak Industrial X-ray Film around the ejector, a single exposure with a 360° x-ray head provides inspection of both thin and thicker sections of the unit.

This is another example of the way radiography saves time and guards quality. It inspects enclosed assemblies. It examines castings for inclusions, voids and shrink. It proves the soundness and continuity of welds. And in every case provides a record for reference.

Radiography can save you time, save money, and build a reputation for high-quality work. If you'd like to discuss how it can help you, get in touch with an x-ray dealer or write us for a Kodak Technical Representative to call.



Radiograph reveals structural parts sound but discovers an air pipe clamp is broken.

Now . . . Ready Pack in ROLLS and SHEETS Kodak Industrial X-ray Film, Types AA and M in 200-ft. rolls (16mm, 35mm, 70mm) and sheets (8 x 10, 10 x 12, 11 x 14, 14 x 17).

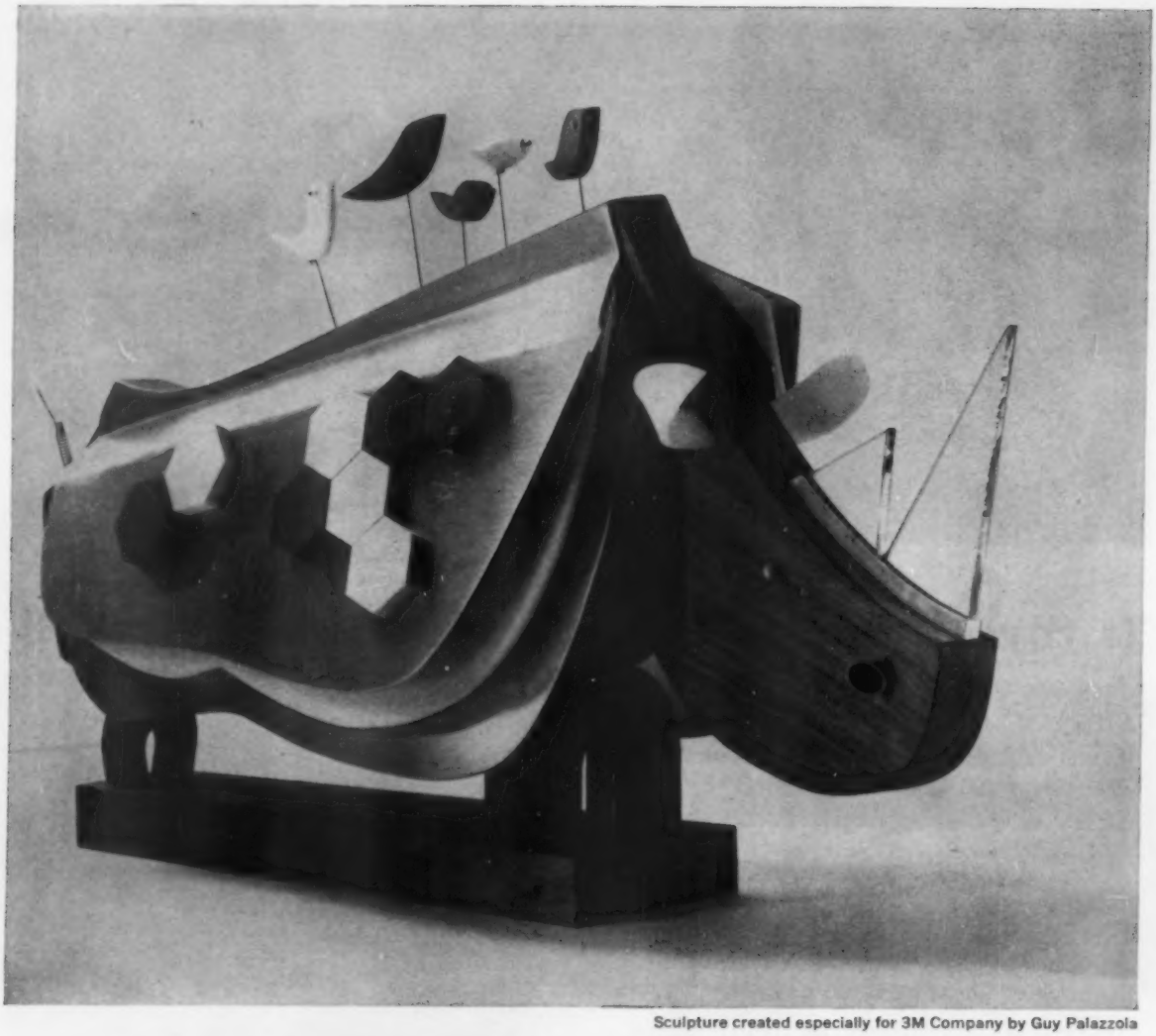
- No darkroom loading—film sealed in a light-tight envelope.
- Just place Ready Pack in position and expose.
- Film protected from dust, dirt, light and moisture.
- In the darkroom—remove film from envelope and process.

EASTMAN KODAK COMPANY
X-ray Sales Division **Rochester 4, N. Y.**

Kodak
TRADE MARK

For more information, circle No. 419

For more information, turn to Reader Service card, circle No. 405



Sculpture created especially for 3M Company by Guy Palazzola

STRENGTH

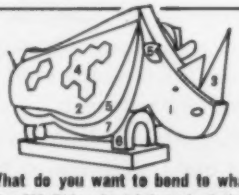
. . . Bonds "strong as a bull rhinoceros" made with SCOTCH-WELD®
Brand Structural Adhesives

Whatever materials you're bonding (to the same or to another material), a SCOTCH-WELD Brand Structural Adhesive bond will give you a bonus of structural strength at the joint, with the flexibility to resist vibrational fatigue. SCOTCH-WELD adhesive bonds distribute stress loads uniformly, and protect the strength and integrity of the materials by eliminating fastening holes, maintaining the finish, and sealing joints against corrosion.

Fatigue tests show that metal-to-metal joints in Convair's 880 jet transports and Air Force F-102A jet interceptors, bonded with SCOTCH-WELD adhesives, will outlast the metal structure they bond together! In industry, too, SCOTCH-WELD adhesives are finding use in joining hermetically sealed metal shipping containers, multiple piece castings and thinner gauge metals, where tear strength would limit the effectiveness of other joining methods.

Look first to 3M! A pioneer in adhesive research, 3M has developed the widest line of adhesives in the industry. These Technical Service facilities are at your disposal. For an accurate appraisal of how an adhesive can add strength, light weight, production economy, and greater design freedom to your process or product, call your nearest 3M Field Engineer or write to: AC&S Division, 3M Company, Department SBHH-61, St. Paul 6, Minnesota.

"SCOTCH-WELD" is a Reg. T.M. of 3M Co. © 3M Co., 1961.



What do you want to bond to what?
The 3M Rhino is fabricated of these materials and bonded with SCOTCH-WELD Brand Structural Adhesives:
1. Wood 2. Aluminum 3. Glass 4. Ceramic
5. Plastic 6. Permanent Magnet 7. Brass

ADHESIVES, COATINGS AND SEALERS DIVISION

MINNESOTA MINING AND MANUFACTURING COMPANY

. . . WHERE RESEARCH IS THE KEY TO TOMORROW

3M COMPANY

For more information, turn to Reader Service card, circle No. 391

Assembly line inspection of steel slabs up to 4 in. thick is said to be possible with a new gamma ray image intensifier system that projects a television image. Gamma ray inspection has previously been restricted to photographic methods because the high energy rays overload conventional fluoroscopes. The new unit uses a small cobalt-60 source and is also said to be useful for rapid inspection of large blocks of solid propellant for rockets.
Source: Rauland Corp., 6001 W. Dickens, Chicago (intensifier); Picker X-Ray Corp., White Plains, N. Y. (camera).

A highly efficient source of electrical energy is a recently developed biochemical fuel cell that uses biological processes, natural in sea water. The experimental fuel cell is divided into two chambers: the anode section holds bacteria, enzymes and organic matter; the cathode contains sea water and oxygen. Heat normally released when bacteria or enzymes consume organic matter is converted to electricity by the interaction of the fuel cells through a dividing ion diffusion bridge. Refinement of the present model may provide a revolutionary source of electrical power.
Source: F. D. Sisler, Geological Survey, U. S. Dept. of the Interior, Washington 25, D. C.

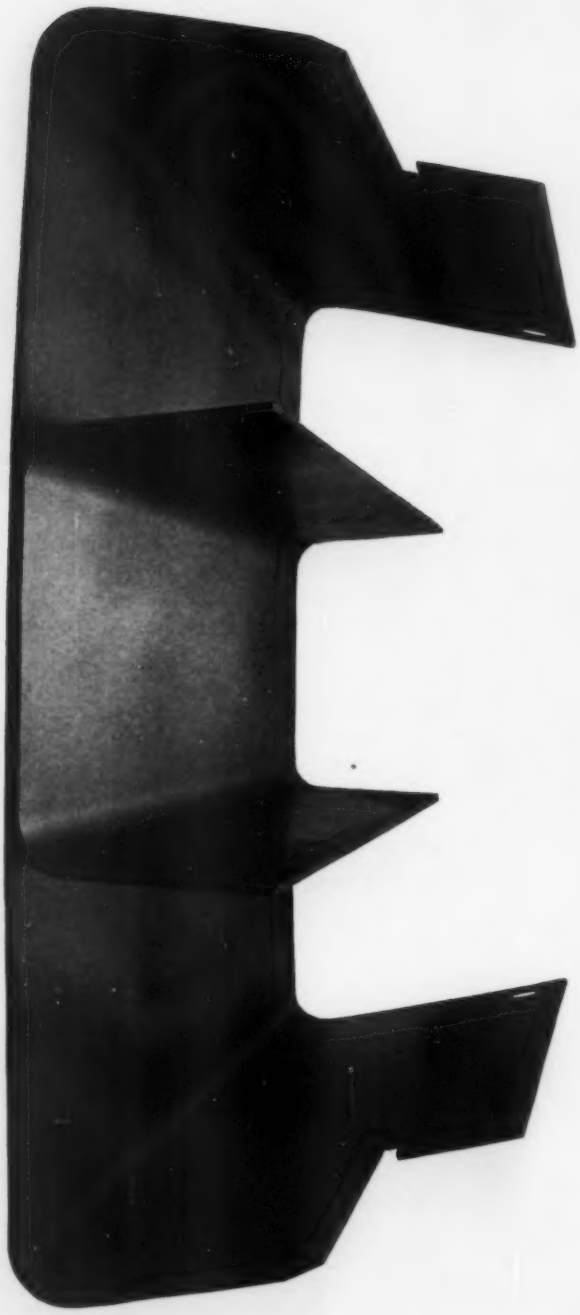
Plastics can crack spontaneously before stressing according to recent research. Spontaneous cracking can suddenly occur between between spherulite (radial crystal growths) boundaries in polypropylene films after 4 min at 250 F. Subsequent stressing inevitably breaks the film along the weak or cracked zones.
Source: L. Baris, Fabric Research Laboratory, Inc., Dedham, Mass.

Electrospark machining causes an exchange of metals between the work-piece and the electrode, according to Polish scientists. Tests run with a variety of electrodes used to pierce carbon steel and aluminum showed the exchange. Quantity of diffused metal is proportional (within limits) to the spark's capacitance.
Source: *Review of the Soviet Technical Press*, Mar 24, '61, Office of Technical Services, Washington 25, D. C.

Reentering space vehicles or manned capsules can be successfully slowed and stabilized in the Mach 3 speed range by balloon-type drag devices, according to a recent report. Polyester-neoprene fabric balloons, 9 ft in dia, slow 500-lb missiles from Mach 3 to speeds where conventional parachutes can take over. The balloon's inherent stability is also effective in stabilizing tumbling reentry bodies.
Source: F. R. Nebiker, Goodyear Aircraft Corp., Akron, Ohio.

Torsion stress resistance of alloy steel shafts can be improved 25-50% in some instances, says a recent report. Carefully controlled heat treatment and shot peening to strengthen the shaft surface, and designing for the best internal stress distribution, are the chief methods of upgrading.
Source: Republic Steel Corp., Cleveland 1.

Blocks of urethane foam used as shipping containers for fragile bottles of frozen tissue culture eliminate the need for dry ice packing. The foam is said to provide an exceptionally shock resistant cushion against breakage. Six bottles fit snugly into cavities in an 8 × 8 × 6-in. block.
Source: American Latex Products Corp., Div. of Dayco Corp., Hawthorne, Calif.



Practical approach to compactness is demonstrated by this flame retardant, interphase insulating barrier for magnetic air circuit breakers. When the equipment was designed, CDF utilized its extensive knowledge of adhesives and post-forming to provide the barriers from a flame retardant, paper base phenolic laminate.

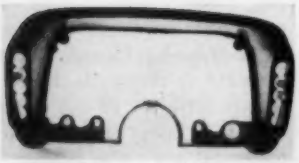
Result: two pieces bonded together to provide three channels in one unit, reducing size and cost, yet maintaining effective electrical insulating properties.

A few facts on the laminate:

Flame resistance: ASTM D-635
...self extinguishing
Water absorption, % 1.8
Flexural strength, psi 12,000
Specific gravity 1.38
Dielectric strength, parallel, kv ... 40

CDF® CONTINENTAL-DIAMOND FIBRE

CONTINENTAL-DIAMOND FIBRE CORPORATION, NEWARK, DELAWARE • A SUBSIDIARY OF THE Bndd COMPANY



Acetal instrument housing for 1961 Valiant.

Zinc headlamp door for 1960 Chrysler (plated).

Acetal Moldings

vs

Zinc Die Castings

To find out how to choose between them, two of our editors set out to interview experienced end-users. Here is their report.

by Malcolm W. Riley and Donald Peckner, *Associate Editors, Materials in Design Engineering*

■ "... Acetal resin, a tough, rigid engineering material designed primarily as a replacement for die cast metals."

"Zinc fights back: basic characteristics make it superior to plastics . . ."

Such statements, one in a news release from a prominent plastics molder, the other a headline in a prominent metals paper, have spurred the "controversy" over acetal and zinc.

What are the facts?

For a starter: Acetal plastics were not developed to replace die cast metals. And zinc is certainly superior to plastics for some applications . . . but not for all.

Each material has combinations of properties that make it best for certain uses. In this sense, they are complementary rather than competitive.

Then why the controversy?

Behind the promotional smoke screen, considerations that have made the controversy real are:

1. Parts from both materials can be produced by high speed production processes which are similar in concept, i.e., die casting and injection molding.

2. Both materials are roughly comparable in cost, i.e., zinc priced at 14.25¢ per lb, or 3.39¢ per cu in., compared with acetal at 65¢ per lb, or 3.34¢ per cu in. (Prices as of Apr '61).

3. Die cast zinc does not have the strength or heat resistance of many of the wrought metals, and thus is most commonly used for economical decorative or functional parts where load-bearing requirements are relatively low. Although thermoplastics are inherently much lower in strength and heat resistance than metals, the acetals are among the strongest and most heat resistant of the thermoplastics. Thus, they have helped to narrow the gap in strength and heat resistance between metals and plastics.

4. Zinc is an old material, acetal a new one. Like any good new material, acetal is not only a spur to new product development but also is bound to replace and compete with older materials in certain existing applications.

From the end user's standpoint, the "controversy" can only be helpful. Competition is bound to stimulate the zinc producers to further development efforts, some of which are already bearing fruit, e.g., recent marketing of a new zinc die casting alloy with improved castability (Zamak-7).

Competition is also bound to stimulate acetal producers to further development aimed at more closely predicting how their materials will perform under various service conditions and under various processing conditions. Competition has also favorably affected materials prices and should continue to do so.

Which material, if either, to use in any given part or product is a decision you have to make. But the next seven pages should simplify the job.

Acetal vs zinc: compare their performance first

Since acetal and zinc are two very different materials, for many applications it is necessary only to understand fully the properties of each in order to make the correct choice. Levels of strength, heat resistance, weight, electrical resistivity and resistance to deterioration are well established. If these factors are of primary importance in your design, you will probably not need to go through elaborate manufacturing cost analyses.

But a caution: it is all too easy to reject a material because of some lack or another when you could, with some thought, put up with it by designing around it.

The accompanying table compares zinc and acetal as well as they can be compared by standard ASTM test methods. Precise quantitative comparisons are not valid because of the differences in test methods used for metals and plastics. But you can get an idea of relative order of magnitude.

Now let's look at performance in some detail.

Strength, stiffness

Among the zinc proponents' main arguments for zinc is its superiority in strength—a fact that cannot be denied. Zinc's tensile, compressive and shear strengths are much higher than those of acetal. In uses where such strength is required, the two materials certainly do not compete.

Interestingly enough, the two materials are quite similar in behavior under tensile stress below the accepted yield point. Neither material exhibits truly elastic behavior, but produces a stress-strain curve with hysteresis. Thus both materials exhibit a degree of "cold flow" or creep at stress levels below the yield point. As a result no generally recognized tensile modulus can be given.

A rough comparison of rigidity and creep resistance can be obtained by "apparent modulus" values. In plastics engineering, the term apparent modulus is used to denote modulus at any given time, taking into account deformation or strain that has occurred due to cold flow or creep. In metals the term used is "pseudomodulus."

At room temperature, apparent modulus of acetal (Du Pont's Delrin) after continuous loading of 3600 psi for one day is about 260,000 psi; according to *Brown*, under the same stress conditions, apparent modulus of die cast zinc (New Jersey Zinc Co.'s Zamak-3) is about 4,800,000 psi—about 14.5 times greater.

Existing fatigue data are not comparable. According to *Brown*, two zinc alloys (Zamak-3 and Zamak-5) tested for 10^8 cycles of completely reversed axial stress at a frequency of 1600 cycles per min have endurance limits of 6875 and 8175 respectively (specimens aged indoors for six months at room temperature). The most comparable fatigue data available on acetal are an endurance limit of 5100 psi for 10^8 cycles at a frequency of 1800 cycles per min at room temperature and 100% RH.

Although impact strength data are not comparable, it is clear that die cast zinc has substantially higher resistance to impact loads of the type delivered by Charpy or Izod test devices.

Die cast zinc, at Brinell 82-91,

TYPICAL PROPERTIES: ZINC VS ACETAL[a]

Property	ASTM Method		Zinc	Acetal
	Acetal	Zinc		
PHYSICAL PROPERTIES				
Specific Gravity	D792		6.6-6.7	1.41-1.43
Density, lb/cu ft			412-418	88-89
Ther Cond, Btu/hr/sq ft/°F/ft	D325		65	0.13
Specific Heat, Btu/lb/°F			0.10	0.35
Coef of Ther Exp, 10^{-5} per °F	D696		1.52	5.5
Melting Point, F			727-728	347
Max Rec Cont Svc Temp, F			200	185[e]
MECHANICAL PROPERTIES				
Tensile Strength, 1000 psi		E8-57T		
At −4 F	D638	E8-57T	44-49	12.6[b]
At 32 F	D638	E8-57T	41-48	11.5[b]
At 70 F	D638	E8-57T	41-48	9-10
At 104 F	D638	E8-57T	36-43	9.2[b]
At 200 F	D638	E8-57T	28-35	6[b]
Elongation, %[c]		E8-57T	—	—
At −4 F	D638	E8-57T	3-4	14[b]
At 32 F	D638	E8-57T	6	15[b]
At 70 F	D638	E8-57T	7-10	12-15
At 158 F	D638	E8-57T	18-24	330
Compressive Strength, 1000 psi	D695	E9-52T	60-87	5.2[d]
Shear Strength, 1000 psi	D732		31-38	9.5
Impact Strength		E23-56T	—	—
Charpy (unnotched ¼-in. bars), ft-lb/¼ in.				
At −4 F		E23-56T	4	—
At 70 F		E23-56T	43-48	—
At 200 F		E23-56T	40-43	—
Izod (notched, ½ x ⅛ x ½-in. bars), ft-lb/in. notch				
At −4 F	D256	E23-56T	—	1.3
At 70 F	D256	E23-56T	—	1.4
At 200 F	D256	E23-56T	—	1.4
Hardness				
Rockwell	D785	E18-57T	—	M94, R120
Brinell		E10-58T	82-91	—

[a] Values cover ranges obtainable in die cast Zamak 3, 5 and 7, and injection molded Delrin and Celcon.
[b] Data available only for Du Pont's Delrin.
[c] Values for zinc are ultimate elongation values; values for acetal are at yield.
[d] At 1% deformation.
[e] Value is for Du Pont's Delrin. Celanese recommends 220 F for Celcon.
Source: Adapted from *Brown* with modifications from literature.

is much harder than acetal. Acetal has a Rockwell hardness of about M94. No reading can be obtained in die cast zinc on the Rockwell M scale.

How necessary is strength?

A comparative ranking of physical strengths and hardness of two materials is of value. The more important question is: What are the physical strength requirements of the part being designed?

The types of parts for which both zinc die castings and acetal have been considered are generally complex in configuration and do not lend themselves to detailed stress analysis. Specifications, for the most part, are based on performance of the final part or assembly, rather than on detailed mechanical strength requirements. Final material selection, then, is made on the basis of simulated and actual service tests. In every case where acetal has replaced zinc, the higher strength of zinc was not needed. In those cases where load-bearing requirements call for a material having more than 8000-10,000 psi tensile strength (minus suitable safety factor), acetal will not be considered.

For equivalent stiffness an acetal beam, according to *Brown*, would have to be 2.44 times as thick as a zinc beam. Because of the lack of detailed stress analysis in most pertinent applications this factor cannot be directly applied. But where rigidity is important, you will generally need thicker sections in acetal than in zinc.

The desirability of a high modulus depends on the type of performance required. For example, A. C. Gilbert is shifting from a plastics material (not acetal) to a zinc die casting for the gooseneck stand for its toy microscopes. This manufacturer felt that the slight degree of flexing possible with the lower modulus plastic did not give the customer the feeling of durability that the more rigid die cast zinc part provided.

On the other hand, low modulus can be a definite asset in meeting other design requirements. Ronson Electric Shaver Corp. found that both zinc and acetal met impact requirements for its shaver heads. But under certain severe impact conditions, the zinc would permanently deform or dent whereas acetal, because of its resilience, would not.

Resilience is also useful for snap fit of parts, and where dimensions may be slightly off in the mating of parts. The lower modulus acetal can permit relaxation of tolerance requirements, since the material can more readily conform to the proper dimensions than a higher modulus material (this, of course, cannot be carried to the extreme where excessive distortion might occur). The resilience of acetal can provide another definite design benefit: a degree of undercut in the part can be incorporated into the mold, eliminating in some cases the need for cam-actuated cores.

In regard to hardness, the pertinent question is: how hard a surface do you need? Although hardness plays a part in the friction and abrasion characteristics of a material, the part it plays is not understood. Also, according to *Brown*, friction and abrasion characteristics are among those properties in which there is little or no information on die cast zinc.

When the Ronson electric shaver head was produced as a zinc die casting, two washer-type bushings of a hardened steel (Rockwell C62) had to be assembled in the die casting to withstand the cutting wear caused by the clipper blade which acted with reciprocating motion on the washers.

Using acetal, Ronson found that it could mold-in the bushings. Tests confirmed that the acetal suffered little or no wear by the cutter. The subject of wear and abrasion resistance is so complex that this specific case cannot be presented as a generalized conclusion. But it is an interesting sidelight.

Heat resistance

Melting points of zinc and acetal have been frequently used to indicate the difference in heat resistance between the two materials, i.e., 728 F for zinc, 347 F for acetal. In all fairness, this is not a useful comparison.

There is no doubt that zinc can withstand higher temperatures than acetal. But the question of one material vs the other in applications where heat is to be anticipated can only be answered by considering: 1) how high a temperature is anticipated, 2) how long and how often the material will be exposed to this temperature, 3) what loads the material must carry during this exposure, and 4) what degree of distortion (if any) is permissible during exposure.

General recommendations given by producers indicate primarily the maximum temperatures they feel they can safely recommend for continuous use of their materials under "normal conditions."

According to New Jersey Zinc Co., "Primarily because of the softness of the . . . alloys at ele-

Ronson Electric Shaver Corp.

***Shaver head** molding of acetal is shown in center. Cutter bar (bottom) reciprocates against two molded-in bearings on top of molding.*

New Jersey Zinc Co.

***Complete Olds dash** is now die cast in zinc by GM's Brown-Lipe-Chapin Div. Rear view shows size, complexity of shape and thinness of wall (0.075 in.).*

vated temperatures, their use is not ordinarily suggested for applications where the castings would be continuously exposed at temperatures above 212 F." For intermittent exposures, of course, higher temperatures are feasible. A further indication of heat resistance: New Jersey Zinc recommends these maximum temperatures and times for baking organic finishes on die castings: ½ hr at 425 F, 1 hr at 375 F, 2 hr at 325 F, or 3 hr at 300 F.

According to Du Pont, "Data lead us to suggest an upper service temperature (for acetal) of 185 F for continuous use in air and 250 F for intermittent service of the type that would be experienced in an automobile. Even temperatures as high as 300 F can be tolerated for brief periods where peak load conditions are not a regular occurrence..."

But acetal producers do not agree. For example, Celanese states that "their new acetal copolymer, Celcon, withstands a continuous use temperature of at least 220 F," and that that figure may go higher with more experience.

Heat distortion temperatures, commonly used for comparative screening of plastics, cannot be used for comparison; no comparable test exists for evaluating metals.

As for retention of strength at elevated temperatures, at 200 F die cast zinc retains about 70% of its initial tensile strength, i.e., it still has 28,000-35,000 psi tensile strength. At 200 F acetal retains about 60% of its 10,000 psi room temperature tensile strength.

Continued aging at 200 F appears from the data available to have little further effect on either material (though aging tests, of course, have been much shorter for acetal because of its newness). After two years aging at 200 F in dry air, die cast zinc's tensile strength at 200 F is still in the 28,000-35,000 psi range. Data available show that after 40 weeks at 200 F, acetal's tensile strength *measured at room temperature* remains relatively unchanged at about 9000-10,000 psi.

Acetal OK for dashboards

The most critical heat resistance requirement that materials must meet for use in auto interiors is about 220 to 230 F for parts located on the dash and subject to possible magnification of sunrays through the windshield. Painted interior parts also must usually pass through a 250 F paint oven. In evaluating its Valiant instrument housings, Chrysler found that acetal met these temperature requirements satisfactorily.

The radical difference between zinc and acetal in thermal conductivity can play an important part in heat resistance. Zinc is a thermal conductor; acetal is a thermal insulator (784 vs 1.6 Btu/hr/sq ft/°F/in., respectively). Exposed to the same incident heat, zinc conducts the heat away from the surface rapidly, whereas acetal tends to concentrate heat at the surface.

On the other hand, low thermal conductivity is an important factor contributing to the "warmth" and pleasing feel of plastics as opposed to metals. According to Ronson, this warmth was a definite factor in selection of acetal to replace zinc in its shaver head.

Weight

Nominal specific gravities of acetal and die cast zinc are 1.42 and 6.65, respectively (0.05 and 0.24 lb per cu in.). Thus, a pound of acetal contains almost 20 cu in. of material, while a pound of zinc contains almost 5 cu in.

Since you need heavier sections of acetal to provide comparable strength, weight differences between parts may not be as great as would appear from these figures. However, most applications where acetal has replaced zinc have been direct replacements using very similar volumes of material.

Light weight is important

In many applications, weight reductions can provide direct or indirect benefits. Benefits in such products as Ronson's electric shaver are obvious. In autos, weight reduction reduces horsepower requirements and car cost, and speeds assembly operations.

No one to our knowledge has determined quantitatively the cost of weight in a car. But *Artinian and Terry* propose an approach by which the cumulative cost of each additional pound in various basic sections of a car can be determined and predicted. Purpose of developing such a cost-weight relationship is to aid in initial decisions affecting redesign of systems and materials selection.

An indication of the cost of weight (figures should be taken qualitatively, rather than quantitatively) can be obtained from data they present on a Plymouth car line. Total cost per car due

to compounding effects of weight ranges from 8.8¢ per pound-change in the rear suspension system to 21.9¢ per pound-change in the weight of the clutch and flywheel. Cost per pound of weight change in the instrument panel is 10.1¢, and the same figure applies to interior trim.

Although these figures cannot be used directly, they do indicate why a decrease in weight from 9.5 lb in zinc to less than 2 lb in acetal for the Valiant housing is significant to Chrysler. And why a possible decrease from 14 lb in zinc to 2.8 lb in acetal for the Chevrolet instrument panel would be significant to General Motors (though acetal has not as yet been selected).

. . . but so is heaviness

On the other hand, minimum weight is not always desirable. Increased weight can be an important reason for materials selection.

In the Princess telephone, the governor weights which control the return speed of the dial are die cast in zinc. The weight of the zinc is required and close control of this weight is critical for proper governor operation.

Lionel Corp. also uses metal wheels (powder metal) and die cast zinc trucks on its two-track HO model trains because of the need for weight. Wheels are insulated by acetal axles between metal wheels and trucks. A. C. Gilbert Co., in a switcher engine chassis for its HO railroad sets, has reverted from acetal to zinc for the wheels for the same reason plus greater realism in appearance.

Electrical properties

Zinc and acetal are electrical opposites, zinc being a conductor and acetal an insulator. Die cast zinc's electrical conductivity is 26% of copper's or 153,000-157,000 mho-cm; resistivity is about 6×10^{-6} ohm-cm. Acetal's resistivity is greater than 4×10^{13} ohm-cm.

For parts that must either conduct or insulate, there is no choice. But parts that do not have any specific electrical performance requirement may present a choice. In parts such as appliance housings, for example, insulators like acetal may accumulate static charges contributing to dust collection, yet on the other hand, may contribute to safety from enclosed electrical equipment.

In many cases the specific design of the component may make the conductive or nonconductive nature of the material an advantage or a liability. For example, the Valiant housing in acetal requires a metal strap to electrically ground the instruments in the cluster. This was unnecessary in zinc. In this case the other benefits of acetal outweighed the disadvantage of having to add another component.

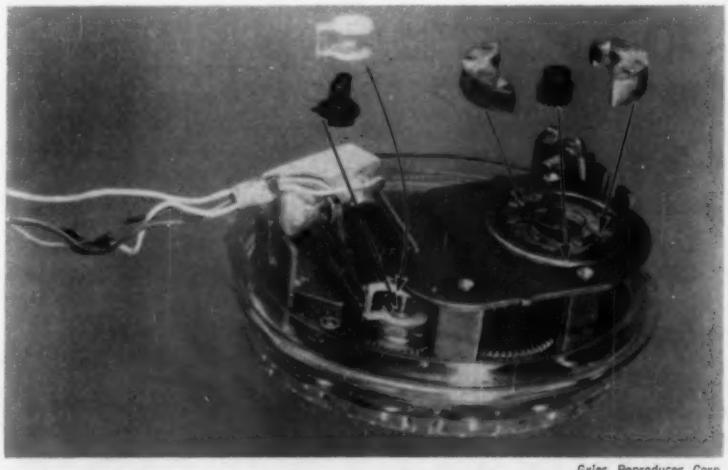
On the other hand, Packard Electric Div. of General Motors feels the nonconductive nature of plastics can be put to use to eliminate much of the "wiring mess" presently existing behind the dashboard of the car. With front-mounting instruments, it can snap-fit electrical connectors into the back of the plastic dash, making the instrument panel essentially an electrical socket. Although present Chevrolet instrument panels in zinc are front-mounting, electrical connections for instruments must be mechanically fastened from the rear and insulated from the conductive panel.

Much work has been done in developing molded-in printed circuits for instrument panels, e.g., Buick is now using them in an ABS plastic panel application developed by AC Spark Plug. It seems safe to assume that entire dashboards will ultimately incorporate all wiring in the form of printed circuits, virtually eliminating back-of-the-dash wiring.

Deterioration

Because of its inorganic nature, zinc is unaffected by exposure to

The Ideal Approach—
Materials Complement One Another



Gries Reproducer Corp.

Dial mechanism *for Western Electric's new Princess telephone uses both acetal and zinc, each to meet specific requirements. The pawl, made of acetal (Delrin) had to be a dielectric, yet have good creep resistance, stiffness, strength in thin sections, and good dimensional stability under variable humidity conditions.*

The governor weights of zinc provide the required weight, coupled with low cost. Other parts shown include cam (far left) and governor pinion (between governor weights), both molded in molybdenum disulfide-filled nylon (Nylatron).

ultraviolet light. Acetal, like many other organic materials, is adversely affected; however, incorporating carbon black filler or ultraviolet filters provides excellent protection for physical properties. Surface hazing will still occur on prolonged exposure to ultraviolet.

Chemical resistance of a material is so highly dependent on the conditions of service and exposure that it is always difficult to generalize. But here, for what it is worth, is the gist of the statements made about zinc and acetal by their producers.

Zinc—Excellent resistance to both metropolitan and rural atmospheric corrosion; also hot soapy water, printing inks, trichloroethylene, carbon tetrachloride, dry illuminating gas and moisture and acid-free hydrocarbons. Fair resistance to pure ethyl and methyl alcohols, glycerine, water and petroleum products. Poor resistance to steam, spray insecticides, animal oils, strong acids and bases, and mixtures of glycerine or alcohol and water.

Acetal—Excellent resistance to most organic solvents, including aliphatic and aromatic hydrocarbons. Not recommended for use with strong acids and alkalis; should be tested for use with dilute acids and weak alkalis.

Engineers interviewed for this article could not make direct comparisons in chemical stability between zinc and acetal. In almost every case where acetal replaced zinc, the die casting had been finished with a decorative plate which also, of course, provided durable protection.

Acetal vs zinc: five troublesome factors to assess

We have discussed performance at some length. But there are other, less clear-cut considerations that can be just as important—or even more important—in determining the final choice. Psychological effects, materials and finishing costs, and other manufacturing costs depend almost entirely on the specific requirements of the part. Some costs, in fact, seem to vary widely depending on whether the part is produced by a custom or captive shop. We cannot draw definitive conclusions here, but we will give you the consensus of the engineers we talked to who have evaluated both acetal and zinc.

Psychological effects

Unfortunately, at this late stage of the game, we must still make brief mention of the possible adverse psychological effect of a product made of plastics. Though acceptance of plastics has grown substantially, prejudice can still be a factor.

Walker Mfg. Co., of Racine, for example, is presently designing an industrial machine lubricator. It is using a die cast meter body, but feels from previous experience that acetal could provide comparable performance at lower cost. Previous surveys of the heavy machine industry, however, have found considerable resistance to anything that does not maintain the heavy, rugged, appearance of the machine. Consequently, Walker feels that acceptance of the lubricator would be jeopardized by the more fragile appearance of the plastic meter. This kind of thinking irks a product design engineer, Walker says, but the attitude is there and must be reckoned with.

Materials costs

The usually quoted materials cost comparison between zinc and acetal is 14.25¢ per lb (3.39¢ per cu in.) for zinc vs 65¢ per lb (3.34¢ per cu in.) for acetal. But remember that the acetal price is for natural color material. Material in standard colors is priced at 74¢ per lb (3.8¢ per cu in.); material in standard colors which are ultraviolet stabilized are 78¢ per lb (4.0¢ per cu in.).

Of course, if a part is to be molded in colored acetal, the same part in zinc would require decorative finishing. Also, if color requirements are not critical, acetal can in some cases be colored by dry blending in the molding plant, at a virtually negligible increase in cost for color.

The effect of reprocessability of materials is difficult to determine from end-users. All zinc scrap can, of course, be repeatedly remelted. Acetal can be reprocessed, according to producers, "as many as four times" without significant change in physical properties. But since quotations by molders or die casters are based on a per-part cost, which includes any scrap costs, reprocessability does not appear to be an important factor to consider separately.

Finishing and decoration

Elimination or substantial reduction of the finishing and machining required after die casting has been an important factor in selecting acetal in a number of cases. One manufacturer says that his zinc parts used to cost 6-7¢ per casting plus about 45¢ worth of deburring, machining and plating. Post-plating inspection in some cases resulted in rejection of the entire 51¢ part. In acetal, the only postmolding operation is clipping the sprues; cost of the final part in acetal is 6-7¢.

Most zinc die castings have flash. Flash removal costs can be minimized by trim dies, but trim dies still constitute a secondary operation. There may be a substantial difference in the amount of finishing required between parts die cast or molded in a custom shop and in a captive shop. A captive operation sometimes permits the production people to work much more closely with the designers to produce the part

closer to the final desired condition.

Should mold wear or improper mold design result in flash on an acetal molding, the inherent resilience of the material makes flash removal more difficult than in zinc. However none of the engineers interviewed cited flash removal as a requirement on any acetal part.

When die cast in zinc, the Ford Econoline truck door handles and window regulators required trimming and a preplating operation, followed by chromium plating. Also, serrations in the grip area had to be cleaned out. Molded in acetal, the handles and regulators require no finishing after molding other than clipping sprues.

Chrysler is planning to use acetal for the push-button of a door latch. The present design uses a zinc die casting which must be trimmed, deburred and plated; a pin is then staked inside and a nylon sleeve fitted over one end. In acetal the design has been altered to eliminate the pin and nylon sleeve, and the part can be used directly from the mold after sprue removal.

On the other hand, according to Chrysler, one of the most important benefits of zinc for nonstructural applications is that it can be plated to give a bright, durable finish. Although acetal can be metallized, first surface coatings (i.e., on the exposed surface) are not suitable for wear or exterior use. If a more durable first surface metallized coating were developed, "many plated zinc parts for exterior auto trim might be seriously re-evaluated."

Molded-in colors vs painting—An inherent benefit of plastics is colorability. Unfortunately, production scheduling problems are presently limiting the full use of colored acetal in automobiles.

For example, Chrysler's Valiant instrument housing is molded in natural color and then painted. From the scheduling standpoint it is less costly to paint the housing in the same production line as the rest of the dash, than to try to produce colored housings separately in the same proportion of colors as that used for production interiors. The problem would be further complicated should interior colors be changed to suit demand during a model year.

Another important consideration is color match. Color matching is a highly difficult art in itself. Matching molded-in colors with the enamel colors of a painted metal dash is extremely difficult.

Packard Electric is currently evaluating acetal, along with several other plastics, for the Chevrolet instrument panel. They feel that the scheduling and color match problems might be avoided by using only a limited number of colors in the cluster, each of which would complement rather than match several of its standard dash colors. Another possibility, if direct matching was required, would be to provide a "break" line between the cluster and the rest of the dash.

One cost consideration that argues for molded-in color, provided scheduling problems could be avoided, is the fact that a special primer must be applied to acetal to secure good adhesion of the final finish. At present, Valiant housings are primed in the molder's plant and delivered to Chrysler ready for final painting on the production line.

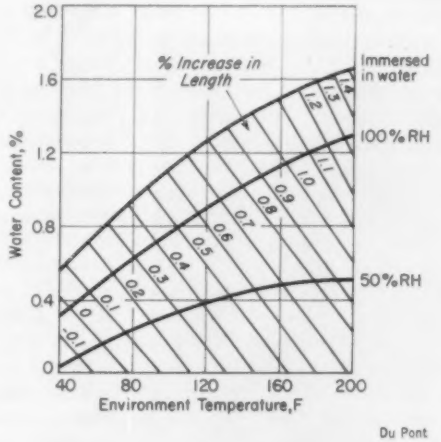
The Valiant housing— Cost is the question

Despite all careful evaluation, sometimes both performance and cost come down to the line at a standoff. Such is the case in the well-publicized Valiant instrument housing.

All of Valiant's 1961 housings are in acetal; performance has been proven. But costs are not so clear. According to Chrysler, present plans call for the 1962 Valiant housing in acetal—the 1962 Lancer housing (essentially the same housing) in die cast zinc. Chrysler feels that for this application acetal and zinc are comparable performers, though the acetal is lighter. By planning production of one housing in acetal, the other in zinc they can get a direct—and more exact—cost comparison.

Such a decision gives Chrysler added flexibility. Should cost of materials, processing or finishing alter during the model year, they could simply shift production to the less expensive material.

Dimensional change *due to environment. To determine, subtract percentage increase in length indicated by initial environment from percentage increase in length indicated by new environment.*



Hot stamping on acetal to produce decorative effects ran into difficulties at first, several users report. But development work with leaf manufacturers has apparently led to satisfactory stamping.

One appearance problem that acetal does have is a tendency to produce "sink marks" where radical changes in section thickness occur. These marks are caused by the relatively high shrinkage of the materials (discussed below). In some cases you can avoid shrinks marks by modifying the design.

Tolerances, dimensional stability

Where precise dimensions are critical, you must generally consider three factors: 1) mold or die shrinkage, 2) effects of aging, and 3) thermal expansion.

In all three areas, zinc experiences less dimensional change than acetal. Zinc alloys have a generally recognized die shrinkage of 0.004 in. per in. On aging, certain zinc alloys experience first a shrinkage, then an expansion. Both are very small. For example, after casting, two typical die casting alloys experience maximum shrinkage (on air cooling) of 0.0007-0.0009 in. per in. Maximum expansion following this shrinkage (under the most extreme conditions of two years in dry air at 200 F) is 0.0002-0.0011 in. per in. So the maximum net change in dimensions from the original size is -0.0005 to $+0.0002$ in. per in.

In acetal, mold shrinkage is about 0.020–0.025 in. per in. The primary effects of aging are changes caused by moisture absorption. Both shrinkage and dimensional change on moisture absorption are mentioned quite frequently because of the effect they have on dimensionals. For example, the graph on p 111 shows, in going from the as-molded dry state to an equilibrium value of 0.22% at 77 F and 50% RH, an acetal molding will increase in size by 0.001 in. per in.

In considering dimensional accuracy, keep in mind that acetal has a much higher coefficient of thermal expansion than zinc, i.e., 5.5×10^{-5} vs 1.52×10^{-5} per °F.

Another dimensional factor that may have to be considered with acetal, as with other thermoplastics, is further dimensional change or shrinkage with aging due to stress relaxation. This can be particularly pronounced at elevated temperatures. Such shrinkage can be minimized either by annealing or by molding in a hot mold. Magnitude of such shrinkage ranges from a low of 0.0005 to a high of 0.004 in. per in., depending on molding conditions and environmental temperatures. Although much as been made of the occasional need for annealing by acetal's detractors, none of the parts discussed in this article required annealing.

The tolerance obtainable by usual commercial practice in zinc die castings is ± 0.0025 in. for dimensions under 1 in., 0.001 in. per in. for larger dimensions. In acetal commercial molding tolerances are ± 0.003 in. for dimensions up to one inch, ± 0.002 in. per in. for subsequent inches. Figures for both zinc and acetal are generalizations; closer tolerances can be held.

One factor that you should bear in mind: In many cases, as mentioned before, resilient plastics such as acetal do not require the degree of accuracy that a more rigid material such as zinc requires. Where fits are required with other parts, the plastic will "give" to some degree, permitting a fit unobtainable without modification in zinc. In many cases this factor has practical importance.

One of the most important consequences of the relatively high shrinkage exhibited by acetal has been the need for cut-and-try die development work to ascertain precise shrinkage allowances for a given part. The amount of such development work has been substantially reduced with experience. A. C. Gilbert, for example, says it can now design a mold "from scratch" to hold molded tolerances within ± 0.002 in. per in. For closer tolerances, e.g., ± 0.001 in. per in., it must gage the specific mold.

Tooling and production

Direct comparisons of mold vs die costs are unavailable. Most engineers believe die casting and injection molding are pretty much a standoff on tooling costs. Even though plastics molds are generally less costly to maintain, mold development costs may easily offset any advantage.

Rate of production possible with zinc and acetal depends primarily on size of the part. According to *Brown*, average production rate for small zinc die casting is 7 shots per min. Such a production rate cannot generally be obtained in injection molding acetal. The highest production rate in acetal mentioned by those interviewed for this article was for a thin-section part made by A. C. Gilbert: 5 shots per min in a 6-cavity mold. On larger parts cycles extend up to a minute each. In plastics, lower thermal conductivity makes cycle time more dependent on section thickness than in metal.

From the practical standpoint, no one interviewed felt that relative production speed was of such importance to their application as to affect materials selection.

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Walker Mfg. Co.

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1

Functional Styling with Wire

■ Formed wire and wire-strip assemblies are being used in a variety of applications which take advantage of the structural and forming properties and the clean, functional appearance of steel and other wire.

One of wire's chief decorative advantages is the ease with which it can be finished. After a part is formed it can be plated with a wide variety of metals. In addition, many types of precoatings are both decorative and durable and do not require further finishing after the part is formed and assembled. The products are made by E. H. Titchener & Co., Binghamton, N. Y.

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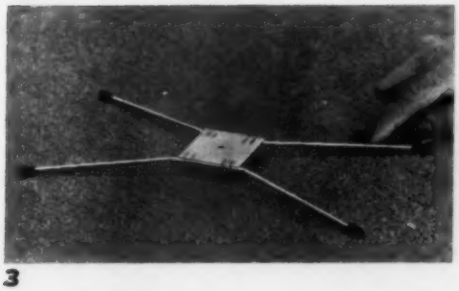

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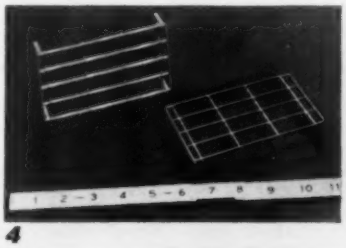
***1** Stainless steel wire guards and grills of this marine stove are electropolished to contrast with the stove body.* ***2** Welded wire shelves of this library book cart are zinc plated, then vinyl coated and baked for a durable and attractive finish.* ***3** Swivel base for a clock radio is a welded wire and strip assembly. The brass plating is protected by lacquer, and pressed-on plastics feet prevent scratching.* ***4** Wire, strip are welded to form this radio speaker grill. The grills are colored with chromate treated zinc plating to match the cabinet colors. Baked clear lacquer protects the finish.* ***5** Snap-on decorative strip for a television set cabinet is brass plated and lacquered. It can be quickly installed on the assembly line.*



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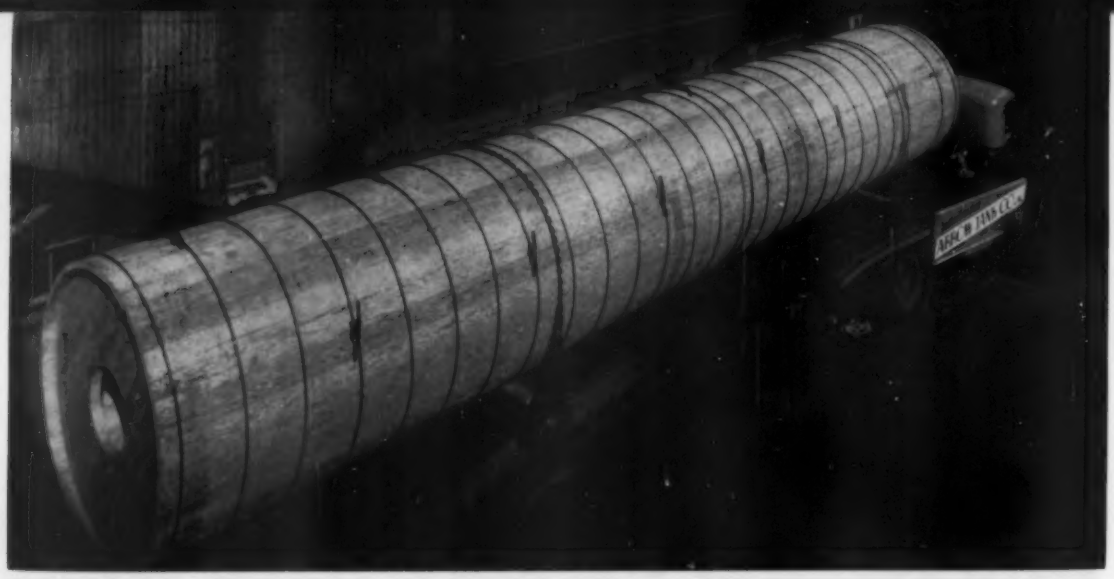


Exhaust stack—*This Douglas fir stack is 6 ft in dia by 32 ft long.*

For low cost, long life . . .

Try Wood for Corrosion

by A. P. Pfeil, *President & General Manager, Arrow Tank Co., Inc.*

■ Amid the glamor of the newer structural plastics and coating materials, wood is often overlooked. But the inherent chemical resistance of certain woods when properly used can provide economical long-life components for chemical resistant tanks, ducts, stacks, pipe and structures.

Briefly, the most important benefits of wood are:

1. Low cost—Wood structures are low in initial cost, and provide long life with a minimum of maintenance.

2. Transportable — Wood tanks and equipment are easy to transport to possibly remote areas. A knocked-down wooden structure is only as large as its largest piece of lumber.

3. Ease of assembly—Wooden structures are erected and assembled mechanically (usually held together with metal hoops, bolts and tie rods), requiring no bulky specialized fabrication or processing equipment. Mechanical assembly permits simple disassembly and reassembly in a new location.

4. Low thermal conductivity—Wood's low thermal conductivity helps maintain constant temperature, both of the contents of the structure and of the surrounding area.

The two most important limitations of wood are: 1) possible difficulty in obtaining economically the proper type and grade of lumber for a particular job, and 2) the fact that wood is a natural product; although you can usually predict performance well, you must allow for the peculiarities of nature.

Woods differ radically. Only specialists in wood construction should select the proper species and grade and design the structure. The purpose of this article is to acquaint engineers and designers with the basic types of wood used for chemical resistant structures and give some indication of the performance that can be expected.

Four types usually used

Four types of woods are most commonly used for chemical resistant structures: Tidewater red cypress, long leaf yellow pine, California redwood, and yellow Douglas fir. All are available commercially at reasonable cost in various grades.

Resistance of these woods to various reagents both at room and elevated temperatures is shown in the accompanying table. The four conditions shown in bold type (NAC, SS, SB and GC) are those which have been arbitrarily selected as indicating little or no degradation of the wood.

Formula for acid resistance

Where results of actual experience are unavailable, acid resistance of a given wood can be evaluated by its composition. The factors that confer acid and decay resistance to woods are high cellulose and lignin contents, and low pentosan content. Consequently, the following formula can be used to determine acid resistance: Cellulose content *plus* lignin content *minus* pentosan content.

The higher the resultant figure the greater the acid resistance.

How woods are graded

Heartwood is the type usually most desirable for chemical resistant structures. Heartwood is that central portion of the tree which has become inert as the tree grows and the sapwood forms on the outer periphery of the trunk. The proportion of heartwood in the lumber is one of the primary bases for the grading of wood. Grades have been established within each species by the various organizations listed at the end of this article.

In timbers of the size normally used for building chemical structures, the top grade in cypress, redwood and Douglas fir is called Tank Grade; in yellow pine it is called Genoa Prime. These grades are specified to be either free from or nearly free from sapwood and other defects.

The next grade is generally called FAS Grade in cypress, Aye Grade in redwood, B&Btr Grade in Douglas fir, and Heart Merchantable Grade in yellow pine. This second grade is generally the same as the first grade except that it includes a larger precentage of sapwood. Both grades can be readily used if the builder makes sure that the sapwood is limited.

Lower grades are called "common grades," and when used for chemical structures are purchased with a specification that they contain at least 85% heartwood.

The term "Select Grade" is often misleading. It merely denotes the third or fourth grade of a species.

Types of cypress

In addition to tidewater red cypress which is the most resistant to chemicals and decay, other types of cypress can be used and are often confused with tidewater red. All types are called American bald cypress. Red cypress and deep swamp gulf cypress are classified as coast type.

All red cypress trees usually grow in swamps. They are slow growing, with high ring density

Resistance

CHEMICAL RESISTANCE OF WOODS[a]

Type of Wood →	Cypress		Redwood		Yellow Pine		Fir	
Exposure Condn[b] →	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot
ACIDS								
Hydrochloric								
5%	**NAC**	—	**SS**	—	**SS**	—	**NAC**	—
10%	**NAC**	FSD	**SS**	FSD	**SS**	FSD	**NAC**	**SB**, S
50%	S, WF	FD, Ch, B, S, NG	S, WF	FD, Ch, B, S, NG	S, WF	FD, Ch, B, S, NG	SWF	FD, Ch, B, S, NG
Sulfuric								
1%	**SS, SB**	—	**NAC**	—	**SS**	—	**NAC**	—
4%	—	**SB, GC**	—	**SB, GC**	—	**SB, GC**	—	**SB, GC**
5%	**SS, SB**	**SB**, FSD	**SS, SB**	**SB, GC**	**SS**	**SB, GC**	**SS**	**SS, GC**
10%	S, FSD	B, FD	S, FSD	**SB**, FSD	S, FSD	B, Sp, FD, NG	S, SFD	**SS, GC**
25%	SSp, FSD	—	SSp, FSD	—	SSp, FSD	—	SSp, FSD	—
OTHER REAGENTS								
Caustic Soda								
5%	SSp, FSD	SSp	SSp, FSD	S, GC	**SS**, FSD	**GC**	S, **NAC**	**SS**
10%	S, **SB**, FSD	—	**SS, SB**, FSD	—	**SS, SB**, FSD	—	S, FSD	—
Alum (13%)	**NAC**	**SB, GC**	**NAC**	**SB, GC**	**NAC**	**SB, GC**	**NAC**	**SB, GC**
Sodium Carbonate (10%)	**SB, GC**	**SB, GC**	**SB, GC**	**GC**	**SB, GC**	**GC**	**SB, GC**	**SB, GC**
Calcium Chloride (25%)	**NAC**	**SB, GC**	**NAC**	**NAC**	**NAC**	**SB, GC**	**NAC**	**SB, GC**
Sodium Chloride (25%)	**NAC**	**NAC**	**SB, GC**	**SB, GC**	**SS, GC**	**SB, GC**	**NAC**	**NAC**
Sodium Sulfide	FSD	—	**SB**	—	**SB**	—	**SS, SB**	—
Water	**NAC**	**NAC**	**NAC**	**NAC**	**NAC**	**SB, GC**	**NAC**	**NAC**

[a] Results indicating little or no degradation of wood are bold-faced, thus providing a general guide to wood selection for various exposures. Specimens were examined after seven days drying following total immersion under conditions given. Tests conducted on 1 × 4 × ¼-in. specimens, seasoned and chosen so as to be as similar as possible to condition of woods when used for equipment construction.

[b] *Cold condition:* 21 days immersion at room temperature. *Hot condition:* 8 hr boiling.

Key: B—Brittle; Ch—Charred; FD—Fiber disintegrated; FSD—Fiber slightly disintegrated; GC—Good Condition; NAC—No apparent change; NG—No good; S—Softer; SB—Slightly brittle; Sp—Spongy; SS—Slightly softer; SSp—Slightly spongy; SWF—Slightly weakened fiber; WF—Weakened fiber

Source: Extracted from report by J. K. Stewart, consulting chemist to Mountain Copper Co., Martinez, Calif.

and ring count, so that cell structure is strong and firm. Even when thoroughly dry, tidewater red contains a natural cypressene oil that is highly resistant to most chemical fumes, liquids and gases.

Deep swamp gulf cypress is similar to tide water red. It is often difficult to separate the two by visual inspection. Deep swamp gulf cypress is somewhat less resistant to chemicals and decay than tidewater red.

Yellow and white cypress (classified as inland cypresses) grow farther from the swamps and do not contain the rich minerals of either tidewater red or deep swamp gulf cypress. They are faster growing and their ring structure is far less dense. They contain very little, if any, of the cypressene oil that makes cypress decay resistant.

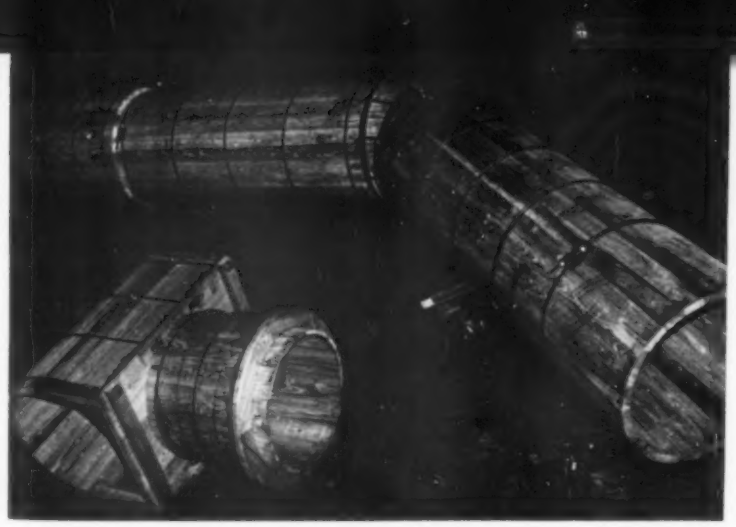
Types of yellow pine

Although many types of yellow pine exist, the two types most commonly used in chemical resistant structures are southern long leaf and short leaf varieties.

The cell structure and general growth of long leaf yellow pine are similar to those of cypress. The heartwood of long leaf yellow pine contains terpene, pinosylvin and pinotol, which provide the inherent resistance to decay and chemicals.

Short leaf yellow pine grows faster than the long leaf variety, and its cells contain little terpene. Because its cell structure is open, short leaf yellow pine can be impregnated or creosoted with a variety of materials to meet specific end-use requirements. Wood preservatives of the creosote type are somewhat similar to tannins and phenolic extractives of wood which are usually drawn from the piece when in contact with hot water. Consequently creosote begins to "bleed" when exposed to hot water.

Creosotes and some other impregnants contain color and impurities that may pollute some liquids or gases. Consequently, care must be taken in selecting impregnated woods to ensure that liquids or gases with which they come in contact will not leach or bleed the impregnants from the wood.



***Vent stack**—Relatively intricate configurations possible are indicated by this long leaf yellow pine vent stack in a paper mill shown prior to installation. Now in service for over two years, stack shows negligible attack after contact with steam, acetic acid, sulfurous and sulfuric acids, and sulfur dioxide.*

Redwood and fir

Both California redwood and Douglas fir are available economically in clear all-heart grades. Both woods contain natural substances enabling them to resist decay and chemicals. Redwood has resins and tannins in the heartwood; Douglas fir has toxifolin which is not only decay resistant but also has slight fungicidal properties. For use in certain chemicals, particularly aqueous sulfuric acid and its fumes, Douglas fir is preferred of the two. It has the greater structural strength and is more readily available in larger timbers of longer length.

Defects: acceptable or not?

Wood used for chemical resistant equipment should have a tight cellular structure to prevent chemicals and fumes from entering the wood easily. All wood is hygroscopic to some degree, but the less the penetration, the longer the piece will last. Sapwood, because it is used to feed the tree in spring and early summer, is relatively porous. Consequently, sapwood is usually considered to be inferior to heartwood. White maple is the exception to this rule; here, pieces that might be termed all sapwood command the highest premium.

Virtually all wood has knots where limbs have grown. Occurrence of such "defects" may weaken the wood or make it more permeable to chemicals and gases. Usefulness depends on the type of knot.

A knot of the sound red or tight variety is caused by a branch which is alive and growing at the time the tree is cut. Such knots have little or no detrimental effect and the wood is still usable in contact with either liquids or gases. Knots that are black or unsound are certainly detrimental and the piece should not be used unless the knot is cut out.

A split or shake in a piece

(continued on p 155)

MORE ENGINEERING & DESIGN

Quenching strengthens copper-babbitt bonds 155

Radar lens made from foam-in-place epoxy 158

Investment cast bracket for jet landing gear 158

Ultrasonic transducer is coated ceramic 160

New Directions in Materials Testing

Until a material's properties and performance can be accurately evaluated and measured, it is of little value as an engineering material. There can be no doubt, therefore, that progress in the development and application of materials is directly dependent upon testing.

How well, then, is materials testing keeping pace with our materials technology? Most technical men will agree that testing is not keeping pace and that, in fact, a serious testing gap now exists. They generally agree that the new and severe service conditions materials must meet, the fantastic environments in which they must operate, and the demands of ever greater reliability have far outstripped our testing know-how and capabilities. There is hardly a product or service area that is not in need of better tests, better testing equipment, better measuring devices, and better data evaluation procedures.

Consequently, today a sense of urgency pervades the materials testing field. There is a growing awareness that we must rigorously reappraise the entire testing structure—down to its very foundations —and that we need new and more sophisticated approaches to solve the testing problems of our modern materials technology.

This Special Report, then, is concerned with this testing gap. It addresses itself to these two broad questions: What are the major testing problems of today and of the near future? What are the hopeful trends, if any, leading toward their solution? To answer these questions the authors critically examine such matters as the new demands on testing, the needs for better apparatus, the contributions electronics and the "new" mathematics are making, and the problems of correlating test results with actual service performance.

M/DE Special Report No. 184—June, 1961

Strength, stiffness, ductility, toughness . . .

by M. SPEWOCK
Manager, Performance Laboratories, Central Laboratories, Westinghouse Electric Corp.

On the whole, users of engineering materials use the results of mechanical tests more than any other performance tests. Now and in the years ahead we will be faced with new loading and environmental conditions that must be simulated in the laboratory and will lead to new and more sophisticated equipment and procedures. But the fundamental problem will continue to be the need to know more about the true relationship between test values and the probable behavior under actual service conditions.

■ Simply stated, the goal of mechanical testing is to provide enough information to permit us to predict mechanical behavior in service. The single, real problem in mechanical testing can also be simply stated: developing information that can be translated into the actual performance of the material in a structure.

Far from remaining stationary, the mechanical testing field is forging ahead with aggressive and fruitful research and development programs to make the task of the engineer easier. Every available tool—from simple, unsophisticated test apparatus to complex, electronically controlled systems—is being used to develop useful information.

Although many gaps exist today in our ability to test for specific properties or in specialized environments, new techniques are being developed to narrow these gaps. Already on the horizon, for example, are ultrasonic measuring techniques that will permit us to measure properties such as yield strength and modulus of elasticity without destroying the specimen. Once such techniques have been fully developed, we will be able to make measurements on a full-scale structure, not just on representative pieces of the structure. This is only one of several promising developments that will be discussed later in this article.

Perfect answers expensive

The surest approach in mechanical testing is to test a model that simulates service conditions. This is often done with results that are meaningful—not in terms of material properties but rather in terms of how a part reacts under service loads. Though it is more meaningful to know how material performs in a structure, clearly this approach entails an impossible amount of testing. To achieve the goal of mechanical testing at a reasonable cost, therefore, we measure separate properties on standard specimens under selected test conditions which correspond to a broad range of service conditions. Such tests measure hardness, yield strength, impact resistance, etc.

Steady progress has been made in developing test apparatus and techniques to meet growing engineering demands. There are, however, two broad deficiencies in mechanical testing today:

- Lack of equipment to provide some of the necessary test conditions, as well as the tools to adequately measure these conditions.
- Lack of proper correlation between laboratory data and actual service conditions.

Data too specific

Because of these deficiencies, materials engineers and designers can use individual properties only as guides to predict service performance. They must examine data in the light of experience and judgment to determine how the material will perform in an intended application.

A two-fold problem generally applies to materials design parameters: we lack data of sufficient breadth and depth for the newer materials and environments; and we lack the analytical tools to utilize existing information efficiently.

In this situation, one fact stands out: information supplied when the need arises in

connection with a new problem has little value beyond that problem. We do not have proper analytical methods to apply the information to other situations. There is barely enough time and money to do the testing needed immediately let alone that needed to obtain information having broad application.

A good example of the wealth of information being developed for specific situations is the data on the effects of stress raisers in a multitude of different situations. In spite of the large mass of available data, however, you are very unlikely to find information that approximates your own problem closely enough to be useful. Clearly then we must find general relationships that agree with existing data. These relationships, in turn, will lead to the development of analytical methods that will allow us to make more general use of test information.

The need for judgment

The engineer's problem does not end when a true measure of a material property is obtained on a laboratory test specimen. It is unlikely that a material will exhibit that same value when it is applied in a structure. Some of the important factors contributing to the inequality are differences in size, geometry and surface preparation. Or it may be that the structural part does not use the property in the same way it was measured in the test specimen, or that the nature of other requirements imposed in service make that property less important in determining suitability of a material. Engineering judgment is needed to pull together all of the data and characteristics that determine the chances for a material to perform successfully.

The following properties, for example, are commonly measured; note the problems that arise in making use of the test data:

Toughness—Many materials can be compared on their ability to resist impact loads—a measure of toughness. We can use the numbers obtained in a test program as a materials selection guide. But we cannot in any way use them to quantitatively predict the impact strength of different-size specimens. The principal problem is not the inability to control metallurgical structure, or machining and processing variables, but the fact that impact strength is highly dependent on such factors as size, geometry and orientation—effects that are not well understood at this time.

Damping capacity — The problems in applying damping capacity data are somewhat similar to those encountered in using toughness data. But here, size and geometry differences between test specimen and structural member are only indirectly involved. The main reason that we can make only qualitative use of damping capacity data is that damping capacity varies with internal stress. Direct application of the data would require precise knowledge about the levels, gradients and directions of stress expected in the structural part.

Creep—In spite of the large body of information developed concerning creep and creep-rupture, straightforward application to designs is not possible; laboratory tests still do not accurately simulate service conditions. A steam turbine may have an intended life of 30 years and its designer would like to know how materials will behave over this long period. Since he cannot wait 30 years for the information to be developed, he may base his decisions on tests run for periods as short as several months. An additional complication: his judgments are based on test results obtained at constant temperature and load, whereas materials in the turbine usually experience unpredictable temperature cycling during service.

Fatigue—Many variables, all difficult to control, affect fatigue strength. Even though fatigue strength can be accurately established in the laboratory, nicks, scratches and discontinuities designed into the part, as well as the chance effects of fabricating processes on surface hardness, will operate singly and in combination to reduce the chance of accurately predicting service life.

Equipment and techniques: the four major problems

Since testing first began, we have had to face two questions: Is the number a true measure of the property? Is the number valid when the material is used in a structure? And if not, how should the number be adjusted?

New technology, especially that of space machines, has added new mechanical test problems to unsolved old ones. Barely able to keep abreast of demands to measure conventional properties with increasing accuracy and under more stringent conditions, we are faced now with questions regarding the effects of microsecond loading, high and rapidly changing temperature gradients, and airborne sound. We must not only devise and build test apparatus to provide the right test conditions; we must also answer those old questions about the intrinsic meaning of the test results and how they may be confounded by testing machine characteristics, specimen preparation and geometry, and testing technique.

1. Today's test conditions

Loading rate — Very high speed loading, formerly characteristic of a few specialized applications, is becoming a familiar service condition. In missiles and rockets and in many non-space machines, structural parts are loaded within milliseconds. A valid appraisal of materials for these applications requires test apparatus capable of applying controlled high speed loads. Even more demanding are the test conditions required to simulate impulse loads such as those present in structures designed to withstand explosive forces and impact loads.

Section size—Testing large cross sections, massive components and even full size structures is often necessary to evaluate properties of materials in specimens whose size and configuration approximate those of structural parts, or to assure reliability of machines. To reach these objectives we need machines having capacities in the million pound range, together with large clear test space. The obvious problem here is heavy capital outlay.

Environment—Structures or materials must be evaluated in environments that match service conditions if data are to be meaningful and reliable. This means that tests must be carried out under various combinations of shock, vibration, irradiation, extremely high temperatures, corrosive atmospheres and high humidity, to name just a few. Often it is the need to eliminate confounding variables, and not the service environment itself, that dictates the test environment. The most common example is the need to test refractory metals such as tungsten and molybdenum in vacuum or inert atmospheres to prevent degradation of material properties by oxidation. Because mechanical properties of most nonmetals are sensitive to moisture content and fairly small deviations in temperature, evaluation and comparison of them is valid only if tests are made under fixed temperature and humidity conditions.

Establishing and closely controlling certain environments can be very difficult; creating temperatures of 4000 F and higher in a test chamber, for example, is not a simple task. Once the temperature capability is developed, however, other factors must be considered. We must maintain a uniform and closely controlled temperature in the test zone, apply loads accurately, and measure specimen displacements accurately. The difficulty in maintaining an artificial environment and the expenditure in time and money increase disproportionately as we increase the size of the test chamber needed, tighten the control limits, and enlarge the extent by which the environment differs from ambient.

Testing of nuclear products superimposes the complex problem of performing various manipulations and making observations without exposing personnel to radiation hazards.

2. Measuring falls short

Providing apparatus to adequately meet the required test conditions is only one facet of our problem. The ultimate in environmental and loading equipment is of no use unless the tools are available to accurately measure mechanical and physical quantities. To meaningfully evaluate mechanical properties we must have accurate repetitive measurement of force, displacement, strain, temperature and other environmental variables. Deficiencies exist in all these areas. Most serious among them are the accurate measurement of temperatures above about 3000 F and the measurement of strains and displacement at constant temperature above about 1000 F. Measuring strain under transient heating is another problem. The data are extremely useful in many test applications but are very difficult to obtain at any temperature.

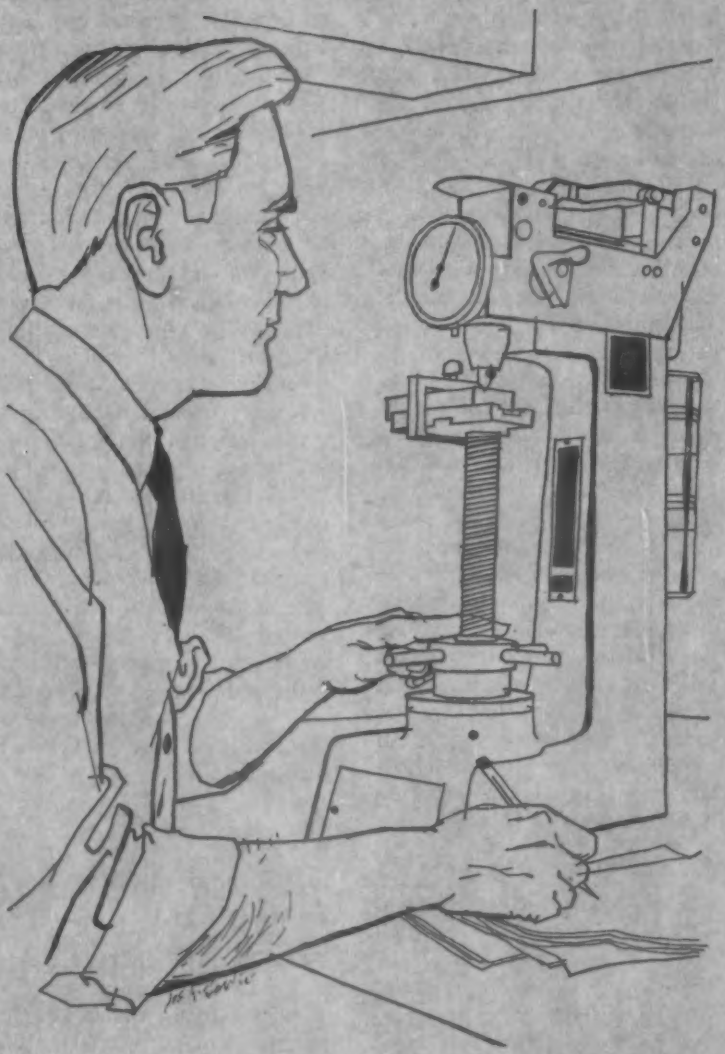
Better coatings are needed to

make refractory alloy grips and fixtures reasonably useful for long periods of time at high temperature. The need here is critical because only the refractory alloys retain their strength at the high testing temperatures; their cost is high, and oxidation problems are seriously hampering efforts to obtain test data on materials at high temperatures.

3. Some properties elusive

Some mechanical properties of materials are difficult to assess not because of limitations in testing equipment, but because the properties themselves are elusive or indefinite or because they are extremely sensitive to variations in specimen preparation and testing techniques. Examples are fatigue strength, brittleness, resistance to crack propagation, and resistance to impact.

We can control the environmental conditions in a laboratory fatigue test with considerable accuracy and precisely determine the number of load reversals required to cause failure. Unfortunately this number represents only the fatigue strength of a given specimen. The reason for this is that we do not understand all the variables determining fatigue strength, and not all those we do understand can we precisely control. For example, the hardness and smoothness of the surface determine, to a large extent, a specimen's fatigue strength. Also important are the nature, type and distribution of imperfections, such as inclusions and voids. Strict adherence to the best metallurgical, machining and polishing techniques cannot produce specimens identical with respect to these variables alone. Obviously then, even laboratory comparison of fatigue strengths among materials is not a straightforward procedure but depends largely on chance and good judgment.



Evaluating brittleness and resistance to crack propagation poses similar problems. Although we have developed a considerable understanding of these properties over the past decade, we still cannot determine susceptibility to these phenomena from conventional room temperature tests. Some empirical laboratory tests

which have been developed are useful in evaluating the relative behavior of materials for specific applications, but less useful in contributing to an understanding of the basic mechanisms.

The Charpy impact test has been used for many years as a measure of material toughness, both for metals and nonmetals. Even results of this simple, widely used test must be critically examined with regard to details of specimen finish and tolerances and the techniques and machines used. A study made by Watertown Arsenal Laboratory showed a wide variation in test results on specimens taken from the same heat of homogeneous steel, machined at the Arsenal, and tested on different machines at various laboratories (which followed their usual test procedures). It took one or more re-runs, accompanied by improvement in procedures and test machine condition, to obtain accurate and reproducible results.

4. Self-defeating tests

Two areas of mechanical testing — measuring residual stresses and evaluating the strength and soundness of welds—are plagued by the necessity to destroy the specimen. These tests are, to a certain extent, self-defeating.

Fabricating and heat treating frequently induce high residual stresses in metal structures. Their direction and location are often critical, and when service stresses are superimposed on them the structure may fail prematurely. In laboratory fatigue test specimens, residual stresses confound test results; residual compressive stresses at the surface increase strength while tensile stresses decrease it. Methods currently available to measure these stresses with acceptable accuracy require destruction of the test piece by sectioning or drilling. Progress has been made in the development of x-ray techniques and some investigators report good results. The x-ray method has disadvantages: it requires very expensive equipment and highly skilled technicians, and it is limited to measuring surface stresses.

Nondestructive methods for examining the interior of welds are not yet adequate. Both the x-ray and ultrasonic methods miss fissures which are serious enough to cause failure, particularly in highly stressed welds and welds in which residual welding stresses cannot practically be reduced by post-weld annealing.

Solutions to these problems are coming . . .

Equipment manufacturers and individual laboratories are attacking—and attacking vigorously — many of the problems posed in the preceding section. Laboratories that need answers in a hurry are developing specialized equipment. Electronic assistance is being used to increase the amount of data that can be recorded in an experimental program, and mathematical analysis is being used more extensively both to predict results and reduce the number of tests that must be made to develop meaningful data.

• • • with better apparatus

▸ Integrated apparatus is commercially available to measure tensile properties of metals up to 3500 F, using an electrically heated specimen. Load-strain characteristics are measured and recorded autographically over a wide range of controlled loading rates up to 0.375 in./in./sec. A more specialized machine that applies full load in a matter of milliseconds is also available.

Private investigators are developing machines capable of applying loads in microseconds. Military laboratories and missile manufacturers, forced to full scale environmental testing to insure reliability, are developing complex, highly instrumented facilities capable of duplicating the extreme environments encountered in rocket flight.

▸ Considerable progress has been made with more conventional apparatus which heats the specimen with an external source. Furnaces can now be used with universal testing machines to provide temperatures ranging up to 3500 F. Individually constructed equipment has exceeded the 3500 F limit.

▸ Top temperatures for tensile and creep tests in vacuum and controlled atmospheres are increasing. Test chambers supplied by several manufacturers can be heated to 4500 F. Again, industrial and institutional laboratories are exceeding this figure; equipment developed under military contract permits tests to be conducted at temperatures over 5500 F.

▸ Materials for grips and fixtures, though lagging behind apparatus development, have been notably improved to satisfactorily withstand high testing temperatures. Vacuum and inert atmospheres present no problem but coatings must be developed to protect refractory alloys when tests are conducted in air. At this writing, the most promising coating—chromium diffused into the parent metal—will provide protection at 3500 F for as long as 2 hr on molybdenum.

▸ Tools for measuring temperature, though still seriously inadequate, have advanced significantly in recent years. In 1957 the upper limit for platinum thermocouple measurements was under 3000 F. Temperatures beyond the thermocouple limit were measured only with rather inaccurate optical pyrometers.

Today, there is a choice of refractory alloy thermocouples and optical pyrometers for measurement to approximately 6500 F. Some of the developments are still too new to permit sound appraisal, but users have had fairly good experience with the tungsten-rhenium alloy thermocouples and with optical pyrometers based on variation in color and brightness.

• • • using electronics

Electronic technology is providing powerful tools to aid the mechanical tester at every step of the testing process from measurement to final computation. Some of these developments include: transducers to sense and signal test variables, programmers to help simulate service conditions, recorders to read and print or plot test data; and computers to reduce large masses of data to usable information.

Most typical, perhaps, is the contribution of electronics in the field of strain analysis. Strains induced in an aircraft wing by simulated flight loads are sensed by hundreds of electrical strain gages cemented to the structure at significant locations. Strain gage output, in the form of electrical signals proportional to the strain, is fed into a high speed recorder which prints the information on magnetic tape for use in a computer. The computer translates the data into printed numbers that tell the magnitude of stresses at each location in the wing structure.

Reliability of missiles is determined by this same system teamed with an equally versatile electronic system which directs test conditions by duplicating those anticipated for the missile in flight. Predetermined conditions are set up in program controllers which, from start to finish of the test, initiate and control the duration and magnitude of such environmental conditions as load, vibration and temperature in the proper sequence.

In less elaborate applications, electronics has been coupled with high speed testing machines to evaluate test specimens at strain rates duplicating those encountered in sudden shock loading.

• • • and mathematics

Although we do not have analytical methods to establish relationships among mechanical properties, mathematical methods are proving useful in collecting, sorting and evaluating data. Among the various currently popular systems, which are referred to as the "new mathematics," statistical methods are the most useful to those investigating mechanical properties.

Statistical analysis is helpful for five reasons:

1. The investigator can design a test program so that all significant variables will be measured.

2. In accuracy of measurement the test variables will be consistent with each other and the goal of the experiment.

3. Individual effects, as well as the effect each variable has on the others, can be developed.

4. A properly designed experiment will develop the most information with the least amount of testing. For example, only 16 tests are needed to investigate an experimental design in which the variables can form 64 combinations.

5. Probably most important, measurements can be mathematically analyzed to eliminate the trial and error approach which depends almost entirely on the investigator's experience and judgment for meaningful analysis.

Statistical analysis classifies the importance of variables according to numerical values. It measures main effects, determines effects of various interactions, and estimates the probable error in results.

The Theory of Similitude is another useful mathematical approach. This theory pre-

scribes the relationships and conditions that a model must meet so that it behaves like the full scale design. Based on the fundamental theorem that the numerical value of all dimensionless combinations of significant variables in the actual system must equal those in the model, this theory tells the investigator how quantities such as length, width and stress, and properties such as modulus of elasticity must be related to achieve results from model tests that are meaningful for the full scale structure.

Watch for these developments

Work is being done in most of the areas where serious gaps exist between the requirements for materials design parameters and the techniques and tools available to measure them.

▸ Promising work is continuing in nondestructive testing methods. Progress has been reported in developing ultrasonic measurement of material constants. Recent claims have been made for the precise measurement of elastic constants, and how they change, by the vibrator-controlled oscillator method. Competent investigators in several laboratories are using x-ray techniques to measure stress to an accuracy of ±3000 psi and they promise that further improvements in accuracy and reliability can be expected in the future.

▸ Failure phenomena are being correlated with empirical data to develop general relationships that can be used to predict material behavior. The emphasis is on the study of crack propagation as it relates both to fatigue and brittle failure. Progress has been reported in: predicting failure of a brittle material under combined stress; fatigue crack propagation studies to determine critical defect size with respect to brittle failure; developing relationships between stress amplitude and number of cycles to fatigue failure, using only static tensile properties; and in studying the effects of multiaxial stress, both mathematically and by tests such as spinning disks to destruction.

▸ Industrial laboratories report that strain gages that can operate up to 1500 F in static tests are in the advanced stages of development. Promising work is going on to improve the sensitivity and stability of birefringement plastic coatings. An optical-electronic method to measure rapid motions, such as encountered in vibration analysis, is coming into prominence and gaining more development attention.

▸ Concentrated efforts are underway at government, industrial and institutional laboratories to develop better instruments for measuring temperature. This effort is aimed at increasing the accuracy and extending the limit of measurement both for new thermocouple alloys and optical techniques. Considering the rate of advances made during the last few years, along with progress currently being reported, there is every promise that the gap in this area should narrow rapidly.

...resistance to deterioration...

by C. J. WESSEL, Director, Prevention of Deterioration Center, National Academy of Sciences-National Research Council

The effects of air, water, sunlight and other natural environments on the properties of materials, not to mention their structural integrity, have been studied for many decades. In contrast to mechanical tests, however, there has been no broad agreement on test conditions and the type of data to be reported. More important, all attempts to simulate in short times the effects of long exposures have had serious shortcomings. Now these traditional problems have been joined by a whole new set of environmental conditions introduced by space flight.

■ The greatest single problem in evaluating deterioration of materials is the youth of the science and the consequent lack of unity and organization of the field. The concept of "deterioration of materials" as a science is new, dating only from World War II. It still lacks clear-cut definition in the minds of many.

What is deterioration? In virtually every application of an engineering material a relationship exists between the material and the environment in which it must operate. If the effect on the material is adverse, the material deteriorates. Although climate was originally considered the primary cause of deterioration, the concept quickly broadened to that of environment in order to explain all forms of deterioration.

Until a few years ago, deterioration by elements of the "natural" environment were the primary considerations. So we thought in terms of moderate heat and cold, sunlight, wind, sand, dust, moisture in all forms, oxygen, ozone, salts, acids, alkalis, mildew and rot organisms, bacteria, insects and rodents, and marine organisms.

Recently the elements of new environments have been brought forcibly to our attention. The elements of natural environment previously considered pale before the magnitude of the elements involved in "induced," "hyper" or "space-associated" environments.

We have suddenly come face to face with effects on materials of such things as tremendous extremes of heat and cold, hard vacuum, electromagnetic radiation, dissociated and ionized gases, plasma, meteoritic dust, auroras and coronas. The kinetics of deterioration has changed drastically. Deterioration that natural environments required months or years to accomplish, these elements accomplish in days, minutes or seconds.

Data unorganized

To a large extent due to the lack of a unified science, testing for effects of environmental deterioration on materials has been scattered, unorganized and unrelated. For the most part each investigation has proceeded without enough thought of its relation to similar investigations by others on related materials or problems.

For example, tests have been carried out on effects of high energy sunlight on the cellulose polymer, on the enzymatic destruction of cellulose by microorganisms in the soil, on the effects of attack by ultraviolet light on polyethylene or polyvinyl chloride, on effects of ozone attack on natural rubber. But little thought has been devoted to the relationships among these modes of deterioration.

Yet all these phenomena involve alterations in the atomic and molecular bonding of fundamental structures and proceed in relation to the energy levels of the deteriorating forces.

Thus, the research needed is that which will give us a more fundamental knowledge of the environmental factors that cause deterioration. When this knowledge is coupled with the results of fundamental research into atomic and molecular structures of materials we will have a chance of understanding the effects of environments, and of predicting what effect they will have on materials.

It is time to develop a basic approach

Techniques now exist that can provide us with an insight into the atomic and molecular structures of materials. These techniques can distinguish what we might call the normal structure from the abnormal structure resulting from exposure to environmental elements. Knowledge of the distinction between normal and abnormal structure, coupled with the known type and level of energy provided by the deteriorating factor, provides a basis for understanding what has happened within the material. Such an understanding helps us to construct materials better able to resist the energy levels of a given attacking environment.

To do this, the elements involved in environments must be organized into a disciplined science. We must determine the energy levels at which each operates under various conditions. Also, we must realize that none of these deteriorating factors operates alone. Never does nature present us with only a single variable. We may isolate single elements and determine their effects on structure, but we must never forget the interrelationships between elements that exist in service.

We must also develop an organized, standardized, meaningful method for reporting the type and degree of deterioration experienced by a material. At present, a variety of techniques of differing degrees of utility are used. Data are given in terms of visual effects, volumetric effects, mass changes, and strength changes, to mention a few. Too often, results reported in one form correlate not at all with results reported in another.

How to go about it

The above, of course, is a highly simplified discussion of an extremely complex field. Its primary purpose is to indicate the philosophical approach that appears to offer the greatest promise in solving the tough problems of testing materials for environmental deterioration.

Probably the most important step we can take to further such an approach is to improve the recognition and acceptance of the field of environmental testing (and testing in general) as an important science in itself. Doing so will attract more engineers and scientists with high qualifications. Too often, testing research is looked upon simply as an appendage to some other type of more important work. The development of new aproaches to testing and evaluation must be approached as research programs *per se*.

Engineering schools and universities should play an important role in improving such recognition. Organized special courses in evaluation and testing research, at the undergraduate or graduate level, would provide young engineers with both the basic educational equipment and the proper attitude to approach environmental test research as a science.

The importance of such an educational approach on the engineering level cannot be overemphasized. The AIA (Aerospace Industries Assn.) has predicted that, whereas 25% of current testing personnel are trained engineers, by 1970 this figure should reach 75%. The situation in the field of environmental testing is similar.

There are other ways to stimulate progress in deterioration testing. Among the most important:

1. Develop and accept suitable definitions of terms and standards of testing.
2. Prepare handbooks of the environments and of environmental testing.
3. Prepare textbooks for use in special college courses.
4. Improve communication of knowledge. It is absolutely essential to reduce drastically the time lag between the origin of new evaluation concepts and the implementation of these concepts in materials specifications.

We must also improve today's tests

Although the fundamental approach to materials evaluation is the one that in the long run will be the most satisfactory, the empirical approach, which has been serving us until now, must be continued and even improved. We cannot lightly throw away our environmental test chambers and wait breathlessly for the magic formula.

Empirical tests are usually simulated service tests by which we hope we can predict how the material will behave in ac-

tual service environments. Another important use of such tests is to indicate what effects fabrication or assembly with other materials may have on deterioration of the material.

The latter information is important. In deterioration or environmental testing the emphasis shifts from one environmental factor to another when a material is transformed into a part, a component, or a final assembly of several materials. Unfortunately the ramifications of such a shift are not always clearly discernible.

For example, the deterioration of a given metal in a given corrosive environment may be readily predictable. But when the metal is combined with another metal or nonmetallic in a specific design, the corrosion conditions may change considerably. Thus, we must consider anew the resistance to deterioration of the overall assembly.

Accelerated tests useful

Granted that simulated service tests are here to stay, what can we say about them? What are some of the main problems with them? And what, if anything, is being done about the problems?

The complexity of most deterioration studies has led to the adoption of actual exposure tests, particularly in the field of weathering and general climatic durability. The length of time required to obtain useful results from such tests has stimulated the use of environmental test chambers in which conditions can be controlled and, hopefully, accelerated to obtain more rapid indications of deterioration effects.

The present state of knowledge makes such testing necessary. No one can spend five to ten years exposure-testing a material while at the same time using it or selling it on faith alone.

But let us fully understand the shortcomings of such tests. Most tests do not actually simulate—do not actually accelerate. Results are at best only indicative of what will actually occur in service and must be treated accordingly.

Five natural environments

The following environments are among those presenting the most troublesome problems in developing meaningful simulated service tests.

1. *Sunlight*—Little correlation exists between outdoor and indoor photodecomposition test results. Lack of correlation is primarily due to the difference in ultraviolet spectral energy distribution between natural sunlight and the various indoor test sources, which differ widely even among themselves.

Other causes include: a) diurnal and seasonal variations in the ultraviolet portion of sunlight, particularly in the short wavelength region which is important in photochemical effects, and b) lack of standard conditions outdoors, i.e., the effects of clouds, haze, smoke, etc., which strongly affect ultraviolet intensity.

Substantial progress has been and is being made in improving artificial light sources to more closely simulate the ultraviolet intensity of sunlight, e.g., use of combinations of xenon and tungsten lamps. But as yet we are far removed from true simulation of sunlight, to say nothing of combining sunlight effects with other environmental factors.

2. *General weathering and durability*—In the final analysis, evaluation of how materials and assemblies behave in various environments relies on how well they stand up in actual weathering tests. That a great deal of reliance is still placed on outdoor weathering tests is indicated by ASTM's publication last year of a report on an entire program of such testing on sandwich constructions ("Symposium on Durability and Weathering of Structural Sandwich Constructions").

There is little correlation between such test results and laboratory simulated tests. Much of this lack of correlation is associated with the unpredictability of sunlight, clouds, haze, geographical location, and manner in which specimens are exposed.

3. *Corrosion*—Corrosion testing is such a large field in itself that comments here must be limited.

The salt spray test, long a subject for controversy, is still used widely with various results. Salt spray tests in the laboratory have resulted in erratic data inconsistent with those obtained by natural exposure. Many efforts have been made to make artificial tests and outdoor tests more comparable. One variation reinvestigated recently is salt fog distribution. Uniform fog distribution was found to provide

consistent results within 9% error. Corrosion rates also seem more correlatable when temperature and humidity are controlled.

X-ray diffraction techniques are proving useful in studying the corrosion process. With a better understanding of the kinetics of corrosion processes, we should be able to develop test procedures for measuring corrosion in the very early stages.

4. *Polymer aging*—The most common method of measuring degradation due to aging of polymers has been to observe changes in tensile properties resulting from aging at elevated temperatures for specified periods of time. Such measurements essentially are only comparative.

The utility of this type of data is questionable. For example, in aging tests on rubber, greater attention has been given to changes in tensile strength than to changes in other tensile properties. Recent work has shown that tensile strength is of little or no value in predicting the aging characteristics of synthetic rubber vulcanizates. Ultimate elongation (strain at failure) now appears to be a more useful measure of the utility of synthetic and natural rubber compounds for applications involving aging.

The use of high energy electrons to vulcanize rubbers may be a helpful test technique in that it introduces less contamination into the vulcanizate and thus reduces the number of variables to be studied.

5. *Biological deterioration*—Biological tests depend to a great extent on living organisms. These organisms may range from single cell microorganisms to highly complex systems such as the rat. In deterioration studies we have relied for the most part on such organisms as fungi, insects and marine organisms.

Many regard the soil burial technique as a method of accelerating fungal deterioration. The technique is difficult to defend as a highly reproducible or even realistic test for those items which are not going to be buried in the soil. Efforts have been made to standardize the burial techniques, and improvements have been made. Further improvement is needed and is possible.

New induced environments

The field of induced environments is so new and such an immense amount of work is going on that we can expect nothing but confusion in test programs for some time to come. The primary problem is to develop methods for simulating such critical and "unnatural" environments as extremely high and low temperatures, extremely high and low pressures, extremely high electromagnetic fluxes, various forms of radiation, and extremely corrosive conditions.

The NASA Research Advisory Committee on Structural Design has advised that new ground-based research facilities are needed to adequately simulate certain hazards of the space environment, including hard vacuum, heating and cooling in conjunction with hard vacuum, hyper velocity impact, and energetic particles.

This same committee has recommended that flight testing of structures and materials is required in order to investigate their behavior under environmental conditions that cannot be adequately simulated on the ground. It points out, for example, that ground simulation of the conditions encountered during reentry at super orbital velocities is presently impossible. Other flight testing programs include recoverable satellite laboratories to study behavior of materials and structures in space, and lunar and planetary probes to establish the atmospheric surface environment on the moon and the planets.

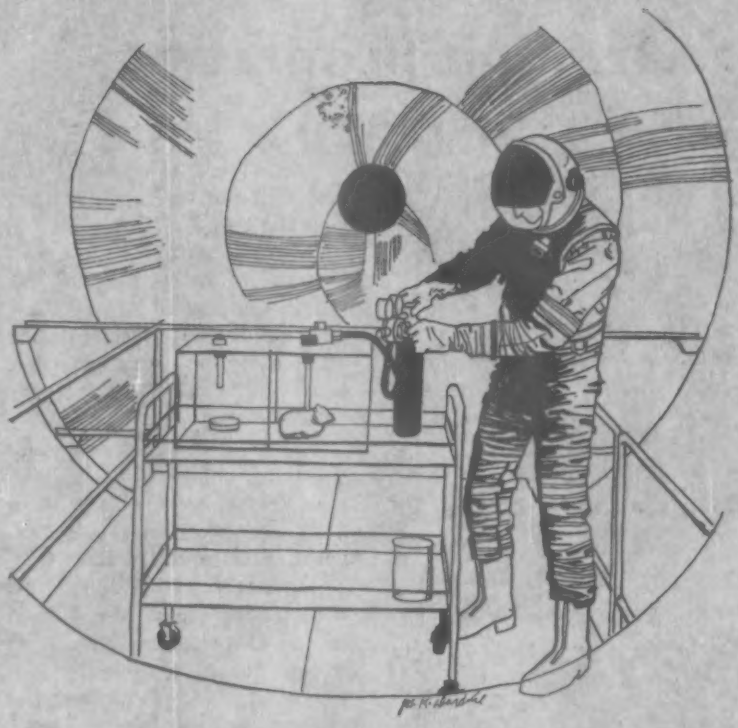
Three of the most critical induced environments are:

1. *High temperatures*—Studies of plasma phenomena indicate that means of testing materials successfully at extremely high temperatures are possible—a hopeful note. Much research is being done on plasma jets, plasma arcs, high intensity arcs, shock tubes and other plasma manifestations. Two promising approaches: the possible development of an a.c. arc to produce a usable plasma, and the combination of a high intensity arc with a mass spectrometer to study the kinetics of evaporation.

A very basic problem in high temperature testing is to develop meaningful methods of measuring the temperatures involved, i.e., upwards of a few thousand degrees Kelvin. We have to substitute such measurements as "color tem-

perature," "brightness temperature," and "radiation temperature." Such values assume meaning only when they relate to corresponding real temperatures. Although correlations at present lack precision, efforts are underway to improve them.

2. *Vacuum*—Equipment available at present that is capable of attaining very low pressures is extremely limited in size. Vacuums much beyond the order of 1×10^{-6} mm Hg (not comparable to the hard vacuums of space) are often difficult to attain. Problems are compounded when other environmental factors must be combined with vacuum. Cost of vacuum equipment is so high that it would appear desirable to combine efforts of many groups to provide common facilities.



3. *Vibration*—Vibration testing is suffering today from a strong difference of opinion over the relative merits of pure sine waves vs random waves as the best way to check out equipment which is to spend part of its working life in vibrating environments.

Some critics say that published specifications that purport to describe an environment in terms of amplitude and frequency are meaningless. They further claim that the simulation of a general vibrational environment in the laboratory is a near impossibility. They feel that it is possible to create a substitute environment whose action upon any resonant system may be considered to be equivalent to the operational environment.

This lack of agreement can impose serious economic hardships on some test laboratories. Many companies feel compelled to purchase relatively expensive electronic power for new vibrators because they feel they may be required to conduct such testing in the future.

Specification testing

The distinction between research testing and specification testing should be emphasized. The former tells us how a material performs under certain conditions and permits us to establish reasonable requirements for the material's performance in service. The term "specification testing" is used here to describe simulated service, prototype actual service, reliability, and quality control tests—tests used to tell us whether a material or product meets the performance requirements.

Specification testing must keep abreast of developments in research testing. But specification testing must be kept as simple as possible for reasons of economy and time.

An important and promising current trend in specification testing is the increased use of nondestructive test methods. Magnetic particle and penetrant methods—two of the original nondestructive test methods — are constantly being refined and more widely applied.

New and useful techniques are being developed as a result of research in both techniques and equipment for x-ray microscopy, projection microradiography, x-ray diffraction, x-ray spectroscopy, and ultrasonics.

. . . friction properties, wear resistance . . .

by MALCOLM W. RILEY,
Associate Editor,
Materials in Design Engineering

From earliest times man, though he may not have been aware of some of the more subtle forms of deterioration, has been acutely aware of the deterioration of materials directly connected with abrasion. Most manufacturers intimately concerned with the problem of wear have developed ways to evaluate the materials they use, but the kind of information that would be of use to designers in all fields seems likely to emerge only as the result of a cooperative effort across many industries. Here are some details of these problems, as well as current ideas in the related field of friction testing.

■ There is no clearly defined, interdisciplinary science of wear-friction. We have developed information to explain the fundamental mechanisms of wear and friction; we have developed empirical information to explain how a particular material performs in a specialized use. But we have not married the two.

Further, virtually all evaluation work has been carried out within distinct materials fields, e.g., metals, ceramics, plastics and elastomers. And the work has been of a problem-solving nature.

Wear and friction are among the more complex—if not the most complex—of all performance characteristics of engineering materials. Wear-friction characteristics depend on the structure and composition of the material as well as its configuration, processing history and the variables of the environment in which it is used. But more important, they depend on the many variables of a second material with which it comes in contact, as well as the conditions of contact.

Definition a problem

The complex nature of the problem has retarded development of a fundamental approach. It has made necessary a "problem solving" approach, each worker developing empirical data to solve his specific problem. With investigators all working in quite different fields, it is no wonder they disagree even on basic definitions.

Most investigators would agree to highly simplified basic definitions of friction and wear, i.e., where friction is the force required to overcome the welding of asperities of two materials in contact with one another, and wear is the loss of material that occurs when these asperities rupture at points other than the weld line.

But beyond this, definitions relate quite specifically to separate fields of study. For example, Howard S. Avery defines wear as the "unintentional deterioration due to use or environment . . . usually a surface phenomenon." The accompanying table shows his classification of wear. This is indeed a broad definition, extending into and actually duplicating to a great extent the whole area of deterioration of materials. But as broad as this definition is, it is aimed specifically at wear of metals, as indicated by the absence of a classification for light or ultraviolet degradation.

Narrowing the field to abrasive wear, there is certainly agreement as to concept. As Avery points out, abrasive particles are a special means of localizing stress on a surface; the wear that occurs is the result of overstressing to the point of structural damage. This concept applies equally to metals and nonmetallics such as plastics. The chief differences are in the ranges of relative hardness involved and in the mechanical properties of surface and abrasive. In both cases, either plastic deformation or localized rupture may be involved.

But when we get more specific, definitions still differ. Avery defines abrasion of metals as "wear caused by large or small, relatively hard foreign particles that are usually nonmetallic." He points out that wear

that commences due to metal-metal contact often becomes abrasive wear as metallic particles are torn loose and are oxidized (becoming, of course, nonmetallic) by friction-induced heat.

In the organic materials field, however, abrasive wear is defined only as the progressive removal of surface material by mechanical action such as rubbing, scraping or erosion.

Basic approach, though costly, might help

The two viewpoints outlined above are symptomatic of the lack of an organized basic approach to the problem. An interdisciplinary, inter-materials approach would not only develop an agreement on basic terms but also lead to an understanding of how the basic wear-friction mechanisms vary with all types of basic structures and types of service.

This does not mean that efforts have not been made to coordinate basic knowledge with practical engineering. Several noteworthy efforts include the MIT conference on Friction and Surface Finish (1940), the ASTM symposium on Wear of Metals (1937), and the University of Michigan's summer conference course on An Engineering Approach to Surface Damage (1958).

Can it work?

Developing our fundamental knowledge to the point that we could make reliable predictions of performance under any conditions is a highly complex assignment at best. At present, such work is scarce.

And who would pay for more? Friction-wear is such a complex study that practical results could not be expected from short-term studies. Most private organizations find such basic work difficult to justify economically. All government-sponsored work in friction-wear has been concerned with solving specific problems.

Furthermore, the complexity of the phenomena raises a serious question in the minds of many as to how useful the results of even a long-term basic program might be. The practicality of a fundamental approach has not been proved.

Most engineers and materials specialists faced with the day-to-day problems of wear-friction are skeptical. Most are doubtful that the ultimate goal of fundamental work can be reached, and most are acutely aware of the time and money required for such work.

Group research an answer

Some are not so skeptical, and some have found that group research can provide an answer to the cost problem.

A project to study metallic wear and friction is now

WEAR—ITS CAUSES AND EFFECTS

Mechanical Causes		Thermal Causes	Chemical Causes
Impact	Friction	Creep Stress Softening Time Deformation Reduced area Scaling Oxidation Corrosion Time Reduced area Crazing Expansion Stress Deformation Stress reversal Reversed deformation Time Cracking Fatigue Growth Graphitization Phase changes Oxidation Transformations Expansion and contraction Induced stresses Development of weak or brittle phases	Solution Heat Time Chemical action Erosion Solution Velocity Stress Intergranular Time Chemical action Electrolytic action Dissimilar Phases Scaling Heat Time Chemical action Diffusion Galvanic Electrolytic action Dissimilar phases Pitting Electrolytic action Dissimilar media
Battering Stress Deformation Rupture Stress Deformation Brittleness Cavitation Stress corrosion	Smoothing Stress Shear Seizing Stress Deformation Welding Galling Stress Deformation Welding Shear		
Abrasion	Vibration		
Erosion Velocity Impact Stress Shear Scratching Low stress Shear Grinding High stress Shear Deformation Gouging High stress Shear Deformation	Fatigue Stress reversals Deformation Cracking Reduced area Corrosion Fatigue Stress Time Corrosion concentration Stress cracking		

Source: *Surface Protection Against Wear and Corrosion.*

underway at Armour Research Foundation under the joint sponsorship of ten companies. According to ARF, the primary goal is "fundamental understanding." This would permit complex wear-friction phenomena to be organized into a science from which quantitative generalizations could be drawn.

According to Robert H. Read, who is heading up the program, the project is intended to answer the question: Why do the basic wear-friction mechanisms operate differently under different conditions? Admittedly the project is limited. Initial objectives are to 1) design and construct the proper test apparatus, 2) select the metal systems and the specific data required to relate wear-friction properties to metallurgy, and 3) generalize the results.

Present studies are limited to unlubricated metal-metal wear and friction. But Read points out that "you have to start somewhere." He is reluctant to predict the direction of future work. Ultimately the work may be extended to lubricated wear-friction studies, but the direction of future work will be set by the body of knowledge as it is developed. It is impossible to predict whether these studies might be ultimately broadened to include all materials.

Friction and wear now two distinct fields

Meanwhile, today's problems have to be solved. The nature of the practical friction and wear problem is such that there is a clear-cut distinction between present methods of testing or evaluating materials for friction characteristics and methods of evaluation for wear resistance.

Most frictional test methods can be further classified as those used in evaluating materials for 1) high friction applications, such as brakes and clutches, and 2) low friction applications, such as bearings. Many of the friction testing concepts are applicable to both metallic and nonmetallic materials.

In wear and abrasion testing there is a clearer distinction between inorganic and organic materials, primarily due to the great difference between the uses for which the materials are intended. Much of the work on inorganic materials is concerned with heavy duty abrasion such as that encountered in mining and earth moving equipment. Emphasis in organic materials is more often on how well a material withstands defacement caused by occasional or less stringent abrasion.

Friction simulated

A standard universal friction test that could provide even a meaningful ranking of various materials does not exist. Values for coefficient of friction (which can be obtained by a variety of different nonstandard testing devices) are relatively meaningless unless they are obtained under conditions identical or nearly identical to those to be encountered in service. As a consequence most friction testing at present is simulated service testing.

High friction testing—Refinement, adaptation and modification of dynamometer testing is probably the single most widespread trend in evaluating high friction materials, e.g., brake and clutch materials.

Dynamometers are being used to simulate with a high degree of precision friction conditions encountered in auto brakes and clutches, aircraft brakes, railroad car brakes and similar applications. Test conditions range all the way from subzero cold to red hot, high speed braking.

A typical evaluation procedure used today to evaluate a friction material, according to American Brake Shoe's Henry Harris, is 1) testing specimens on a "friction machine" which gives the coefficient of friction as well as an indication of degree of wear; 2) dynamometer testing under conditions simulating those to be encountered in service, which ranks materials more precisely for a particular application and gives a better indication of how they will actually perform; and finally 3) actual service testing.

Harris points out that the precision with which simulated service tests on a dynamometer can predict how a material will perform depends on the type of application. For example, railroad car wheels and braking mechanisms are highly standardized because of the need for interchangeability of cars among various railroads. Consequently dynamometer tests on railroad car brake

materials can produce results clearly indicative of actual performance.

On the other hand, designs of automotive brake mechanisms differ from manufacturer to manufacturer — and even from model to model. The only sure measure of automotive brake materials is test track or road testing in the car.

The complexity and specialized nature of the evaluation procedure can be indicated by the number of factors one manufacturer (American Brake Shoe Co.) uses to rate materials for auto brake linings alone. In addition to four physical properties, ten "friction properties" are given qualitative ratings, including cold performance, stability with temperature and pressure change, fade resistance, recovery from fade, resistance to initial fade, wet friction, and resistance to glazing.

Low friction testing—The majority of evaluation methods for low friction materials consist of bearing tests. All such tests have been developed independently and none has been accepted as standard. But the purpose is usually identical: to test the material in the form of a bearing at various loads and speeds, and provide data on coefficients of friction and limiting PV values.

Other methods, such as pulling or sliding weighted specimens along level or inclined planes, are also used—primarily to develop frictional values for comparative ranking of materials. Use of such values for materials selection, or even screening, is highly dubious.

Wear resistance: ranking tests predominate

Although little related work has been carried out in wear and abrasion resistance testing of inorganic and organic materials, a similarity in approach does exist. In short the basic approach consists of first developing laboratory tests to produce empirical data that provide comparative ranking of materials, and then running simulated or actual service tests.

The three criteria outlined by *Avery* for a good laboratory test for abrasion resistance are as valid for organic as for inorganic materials:

1. *Reliability*—Tests must have proven reliability or reproducibility. The degree of reproducibility, once determined, can then be used to judge how much reliance you can place on test results.

2. *Ranking ability* — Tests must have proven ability to distinguish between various materials and rank them on a basis of merit.

3. *Must be validated*—Test results must be validated by correlation with service test results.

The first two requirements have been met quite well by a number of proprietary and standard test methods. But validation is a major problem. As Avery points out, performance data from the field are seldom in sufficient detail to validate laboratory test results. Also, to provide validating data, service tests themselves must be reproducible and have ranking ability. This is seldom the case.

Although there are no standard abrasion test methods for metals, a substantial amount of experience has accumulated through independent efforts. So, although there is little industry-wide agreement on a single testing procedure, many existing proprietary methods provide data that are useful in solving materials problems of individual organizations.

For example, American Brake Shoe has classified abrasion into three types and developed a ranking test for each type. These classifications are 1) low stress scratching abrasion, similar to sand erosion, 2) high stress grinding abrasion, similar to that encountered in ball mills, and 3) gouging abrasion, such as that encountered in rock crushers. Although this classification is not accepted completely throughout the field, other approaches are similar.

Both the classification and the test methods are based on a real need for simplification. If an engineer can recognize a dozen basic factors affecting wear and abrasion, but cannot assign them coefficients or relative weights, he cannot derive a valid prediction. Simplification should lead to canceling out all trivial wear factors, leaving one or more dominant variables. If we can evaluate these against the properties of the materials involved the possibility of valid prediction becomes a probability.

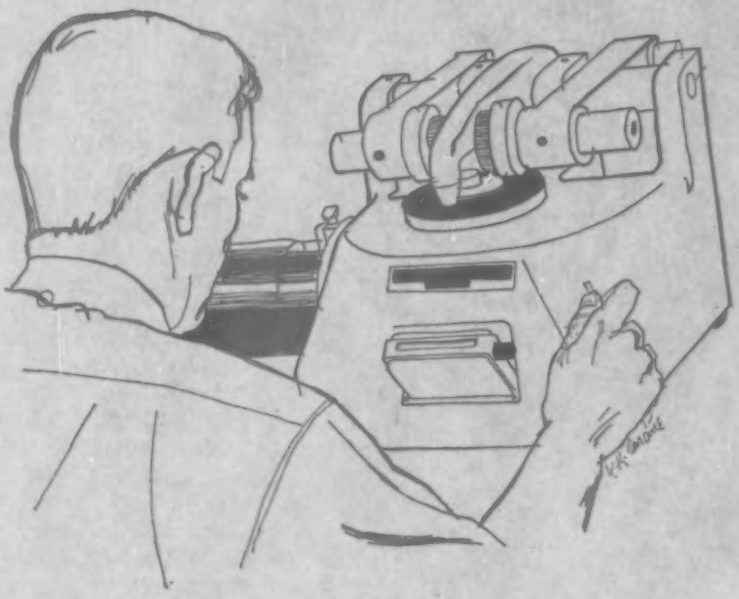
Organics: many tests

The field of organic materials, particularly the synthe-

tics (i.e., plastics, synthetic elastomers, synthetic textiles) is much younger than the metals field. Possibly because of this youth and vigor, standard test methods for measuring abrasion resistance have been agreed upon. But the purpose of these tests is still to provide a ranking of materials, rather than to attempt to predict service life.

The status of testing technology in plastics is put accurately by *Sias*: "A review of the literature for the past 20 years shows that . . . there are more test methods than absolute results. Tests have been run using grinding wheels, fresh sandpaper surfaces, shoe soles and tooth brushes with sand, wind blown or falling particles, rain drops and even washing machines to obtain a reproducible wear or abrasion factor. Some of these tests, including the Taber and NEMA (National Electrical Manufacturers' Assn.) abrasion tests, have been proven to give comparative results but the exact meaning in terms of the life expectancy of (a product such as) a school desk top has not been determined."

There are four ASTM standards for plastics alone, each aimed at measuring a different type of abrasion. Specifically, they measure 1) general abrasion resistance of plastics (by both loose abrasive and bonded abrasive or abrasive tape), 2) abrasion resistance of transparent plastics, 3) mar resistance of glossy plastics, and 4) scratch resistance of plastics (actually the resistance to defacement by sharp particles).



These classifications are not as simple as they might sound. For example, in outlining the scope of the scratch hardness test ASTM says: "The general term hardness includes such varied properties as resistance to indentation, abrasion (sic), cutting, plastic deformation and scratching."

A survey by *Lever and Rhys* lists 38 different tests developed for measuring abrasion resistance of elastomers, plastics, coated fabrics, fabrics and thin films. And this listing is far from complete.

Most such tests have been developed by one laboratory or another in an attempt to more closely characterize abrasive conditions to be found in specific types of service. One materials producer, for example, in attempting to compare his materials with others in abrasion resistance, provides comparative weight loss data obtained by 1) Taber Abraser, with a specific wheel and load, 2) ball mill tests in a specific ball mill with specific balls, 3) a wire drag test, in which a fine wire is pulled continuously over a cylinder of the material, and 4) a sander test, in which football cleats made of the material are pushed against the belt of a wet sander.

The major problem still exists: predicting service life of a material in a given abrasive environment. Although such devices as the Taber Abraser have wheels designed to provide abrasion "like that of normal handling, cleaning and polishing," or like that of floor materials when "subjected to underfoot wear," or the cutting and tearing action encountered during severe abrasion, the number of service variables has precluded direct correlations between test results and service life.

. . . color, gloss, texture . . .

by RICHARD S. HUNTER,
Hunter Associates Laboratory, Inc.

Unlike the tests discussed earlier in this report, the scientific measurement of appearance is relatively new and is immensely complicated by the introduction of the human eye as the arbiter of acceptable quality and performance. No test yet devised can compensate for all the variables of light and position likely to be encountered in service. But continued refinement of tests for color, gloss and texture is certain as long as the present heavy competition for sales persists. For today, appearance often determines the success of a product.

■ Just what do we mean by appearance anyway? Actually, the appearance of a surface is very complicated and depends on many factors such as color, gloss (or luster), haze, shape and texture, and several other characteristics. All of these combine in a complex way that make description and measurement very difficult.

Measurement and specification of these visual characteristics are further complicated by the fact that the human eye is an exceedingly agile and sensitive instrument. Our eyes are quite remarkable: they can distinguish over four million different shades of color, and they can distinguish two lines as separate if the angle between them is as little as one minute of arc. Today's instruments cannot always match such performance and their limitations restrict our present ability to measure appearance.

Although the eye is an agile comparator, it is a relatively poor memorizer. Despite its ability to distinguish roughly four million colors, the eye contains no meters and cannot assign numbers to colors so that they can be recorded and subsequently identified. Even a trained eye can only memorize and identify 250 colors. This means that it is much easier to duplicate a color to satisfy one's memory of the color than it is to duplicate a color that will be seen side-by-side with the original specimen.

Measurement is also complicated by the eye's susceptibility to fatigue and to bias based on previous experience. Two persons looking at the same specimen can, and often do, disagree about the way they match each other. Thus, they will also disagree about the changes needed in a formula or process to make one appearance attribute match another.

Quite naturally, designers and engineers tend to think of appearance characteristics such

as color, gloss and texture as independent variables which can be measured separately. This is extremely difficult to do. Both color and gloss, for example, tend to change with angle of illumination and viewing angle. Interrelationships of this kind make complete specification of appearance very cumbersome and complicated.

Starting with the announcement of Munsell's well known color chips or plaques in 1905, appearance specialists have steadily designed a series of instruments which can test and measure appearance characteristics so that they can be specified and controlled with a reasonable degree of accuracy. It is easy for the layman to look back on the phenomenal development in instruments and think that exact numbers can be assigned to all appearance characteristics. Unfortunately, this is not the case. Many testing problem areas still remain and the measurement of some appearance properties—notably texture and finish—has received surprisingly little attention.

Furthermore, despite all the work that has been done on rating the appearance of nonmetallic materials, we have at present no standardized optical methods for measuring the appearance characteristics of metallic surfaces (see box). Thus, of necessity, the following discussion applies to nonmetallic surfaces and finishes.

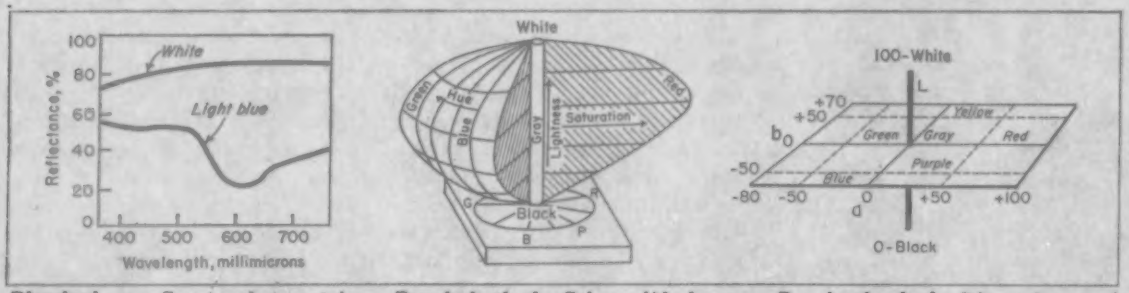
Color: it is hard to simulate the human eye

Measurement of color is complicated by the fact that it is an exceedingly complex phenomenon. Despite this complexity we can separate the methods of measuring and observing color into three main types: physical, psychological and psychophysical. The differences between them are illustrated by the drawings below.

Physical measurements reflect the physical basis of color —the spectral capacity of an object to reflect or transmit different wavelengths of the visible spectrum. Thus, the color of surfaces of material can be represented by spectrophotometric curves of reflectance. Similarly, the color of bodies such as clear glass and liquids can be represented by curves of spectral transmittance rather than spectral reflectance.

Psychological measurements and observations are based not on instruments but on what the eye actually perceives when it looks at color. The eye does not perceive a spectrophotometric curve nor does it have any way of letting us know what wavelengths comprise the light it receives. It perceives psychological attributes such as hue, lightness and saturation which can be described and measured on a color solid as shown.

Psychophysical measurements, as their name implies, are a combination of psychological and physical color attributes. Measurements can be made by combining a psychological color solid and instruments that can precisely locate color attributes such as redness-greeness, yellowness-blueness, and shades from black to white.



Physical *— Spectrophotometric curves show percentage of light reflected at each visible wavelength.*

Psychological*—Color solid shows hue, lightness and saturation.*

Psychophysical*—Dimensions of reflectance (R_d), redness-greenness (a) and yellowness-blueness (b) are used in formula to obtain color difference value.*

Psychophysical measurements are hampered somewhat by the fact that data can vary with changes in the geometric condition of observation and illumination as well as the color of the illuminant. Thus, a specific color measurement applies to only one of many possible observing situations and is only a partial, not a complete, measurement. It would be impossibly cumbersome and wholly impractical to make complete measurements embodying all possible geometric and spectral observing conditions.

Visual Identification

Visual identification of color based on the so-called psychological attributes of color is advantageous in that the operation is simple. One of the most widely used visual tests is the Munsell color system containing 500 to 1000 color chips of permanent paint which are systematically arranged in a color solid. Intervals of value (lightness) and chroma (saturation) are represented by numbers. And the principal hues are represented by letters, with either letters or numbers to identify intervals within each of the ten hue ranges.

The combined use of the eye and color chips provides a relatively fast and inexpensive system. However, it does not provide precise color identification because the observer can be confused when comparing chips with specimen surfaces that are different in structure and texture.

The Munsell system has an interesting peculiarity that can be vexing to technologists who work with colored materials. Because the constant value color planes are perpendicular to the black-white axis the system deals in psychologically idealized, horizontally constructed lightness planes. However, the average materials technologist seldom thinks of color in flat planes because color does not vary this way in most products. He is used to dealing with mixtures of whites, colorants and sometimes blacks which tend to produce color variations along diagonal lines rather than the horizontal planes and vertical saturation scales found in the Munsell system.

Color Instruments

We can use three types of instruments to measure color: spectrophotometers (physical), tristimulus reflectomers (psychophysical), and trichromatic colorimeters (psychophysical). In spectrophotometers a prism or grating isolates wavelengths in the visible spectrum to provide information on reflectance or transmittance as a function of wavelength. Reflectometers use at least three filters, these transmit rather broad spectral bands corresponding to the spectral response function of the standard observer and each one provides a value of reflectance. Colorimeters also use filters but instead of providing reflectance values they give numbers corresponding to position in the color solid.

None of the color measuring instruments now available is importantly better than the human eye in detecting certain small color differences. Although they can detect differences in the vertical dimension of the color solid with greater precision than the eye, they are not as precise in measuring horizontal differences. For example, in the red-green dimension, tristimulus reflectometers and colorimeters must detect signal changes of only 0.03% in order to equal the best eye in detecting color differences.

Color scales and formulas

All of these visual and instrumental techniques have to be used with some form of color scale or color difference formula. Wavelength data obtained from physical tests can be given numbers that correspond to our visual impressions of color and the response functions of the human eye. Thus, so-called "standard observer" procedures have been devised which consist of formulas giving the response of each of three assumed photochemical processes in the eye to light of each of the wavelengths of the visible spectrum. Using these response functions (designated $\bar{x}$, $\bar{y}$ and $\bar{z}$) we can derive the dominant wavelength and purity, dominant wavelength being purely a psychological measure of color.

Unfortunately, because color scales are based on matching mixtures of lights, we cannot use them in any simple way to adjust coloring ingredients when we want to color materials. Colorants such as the pigments used in paints and plastics and the dyes used in textiles impart color chiefly by absorbing or "subtracting" more light of some wavelengths than others. Thus, it is quite complicated to compute the final color of a mixture from color

values of each of its components. This is the reason why the mixing of pigments, stains and dyes is still such an art.

However, some of this art may be disappearing. Just within the past year a computer has been developed that can mix colorants electronically. Called the Colorant Mixture Computer (COMIC), the new device is expected to be a valuable aid in formulating the color of plastics and paint.

Despite the fact that CIE (standard observer) tests assign different values for specimens that differ in color, these instrumental designations are usually unsuitable as a measure of actual visual differences. Thus, a number of color scales have been developed that give the user an approximate and uniform measure of color perception. Most of the color scales and their associated color difference formulas are based on spacings in the Munsell color solid which was designed to provide uniform visual spacing under well standardized conditions of observation.

In using color difference measurements, we should bear four limitations in mind:

1. "Uniform" color scales are not perfectly uniform. Take the National Bureau of Standards units of color difference, for example: it is quite possible for 1 NBS unit to be visually as large as another of 1.5 or even 2 units because of imperfections in the scales or spectral errors in the instruments.

2. The relative perceptability and commercial acceptability of color differences often are not the same. Frequently, we may not tolerate a small difference in hue because we know it can arise from using different materials. In contrast, we may accept a large difference in saturation or lightness because it can conceivably arise from a difference in illumination or viewing angle rather than from a difference in materials. With the color ivory, for example, a customer may not tolerate a hue which is one unit either redder or greener, but readily accept a one-unit difference from the standard in lightness or saturation.

3. A single color difference measurement under one type of light is often not sufficient. As is well known, colors can be drastically changed by the type of illuminant used. Frequently, a match that is good in daylight may not be good under fluorescent light. It is desirable to check specimens under at least two illuminants—standard artificial daylight and lamplight—and frequently under a third, fluorescent light. An instrument that permits switching from one type of illumination to another would be useful.

4. Hue, lightness and saturation alone are often not a complete specification of color. Gloss, texture and other geometric effects can affect color appearance, as indicated earlier, and the effects of these factors do not show in color difference measurements.

Gloss: complex and hard to measure

To the average person, gloss is the property of a surface that gives it a shiny or mirror-like appearance. But gloss is a much more complex phenomenon than most people realize and is a very difficult property to measure.

The materials specialist concerned with appearance would like to have a single instrument that will give a gloss rating for all types of materials and surfaces. Unfortunately there is no single reflectance scale that will give us values that correlate with the gloss appearance of all surfaces.

Six types of gloss

Studies conducted by the author in the 1930's showed that gloss is made up of at least six different types of visual criteria and within each type there may be six to ten measurement scales, each with a different purpose. Since 1936, the establishment of these six gloss criteria has made it possible to set up successful gloss ranking procedures and to test many different materials. Also, despite the multiplicity of types, appearance specialists have usually found that only one or two gloss criteria establish the appearance of their product; thus, important gloss differences can usually be measured whenever the appropriate gloss scales are selected. Following is a breakdown of the six types of gloss and some associated measurement problems:

Specular gloss and sheen are actually the same except that the viewing angle is different. Specular gloss is perceived at medium viewing angles as the shininess of a surface and the brilliance of its highlights.

Sheen is perceived at grazing angles. These two types are probably the most important gloss criteria and fortunately they can be measured by standard instruments without any significant problems.

Contrast gloss as its name implies is the contrast between specularly reflecting areas and adjacent areas. The property can be measured without too much difficulty and the measurements are meaningful.

Absence-of-bloom and *surface haze* are the same to paint specialists at least, except that bloom can be wiped off and haze cannot. Absence-of-bloom is an important gloss criterion, especially for high gloss and semigloss surfaces on which reflected highlights can be seen (e.g., wall tiles). Haze is frequently a problem with industrial finishes and is often found to be caused by improper baking or inadequate pigment dispersion.

To date, the standard conditions for measuring absence-of-bloom have not been worked out. However, there is no barrier to the solution of these measurement problems. It is just a question of people getting together and working out the right techniques. Actually, there is not much pressure to work out a standard test because users have found in almost all cases that a 20-deg gloss test, although not designed for measuring haze, provides them with all the information in this category they need to know.

Distinctness-of-image gloss is a measure of the distinctness and sharpness of mirror images. It is very difficult to measure mirror fidelity photometrically because the human eye has a higher resolving power than the best available instruments. The eye, for example, can detect angular differences as small as 0.01 deg between two points, whereas instruments usually have resolutions of 0.5 deg and in some cases 0.1 deg.

Narrow angle measurement of gloss is also difficult because specimens must be very accurately positioned and quite flat. An instrument cannot differentiate between loss of specular-beam light flux due to poor image reflecting quality and loss of flux due to surface curvature. This is an important practical problem because the eye can readily distinguish between these two effects. Photometric instruments, unlike the eye, cannot discriminate between images that are distorted in size and shape by non-flat surfaces and those that are diffused by microscopically rough surfaces.

A distinctness-of-image glossmeter designed by Middleton and Mungall and refined at our laboratory uses a scanning principle to obtain very high resolution and compensates in part for specimen non-flatness.

Because of the high accuracy provided by photographic prints it has been proposed that they be used to measure distinctness-of-image gloss. Some promising work has been done in this area but as yet no standard test methods have been devised.

Surface uniformity gloss derives from the uniformity of a surface or, stated another way, from the freedom of visible nonuniformities. Because it is not a function of reflectance and more a function of texture it is questionable if, strictly speaking, surface uniformity is a gloss attribute. However, experience shows that the visible texture of a surface can affect the viewer's judgment of gloss.

To date, no instruments have been devised for measuring surface uniformity gloss. The problem is important because users would like to detect and control spotty or uneven areas. The problem has not gone unnoticed and there is hope that measuring instruments now under development will prove suitable.

Other gloss problems

It has been estimated that the ASTM D523 test for 60-deg specular gloss is used for 75% of all gloss measurements made today. This workhorse test precisely separates finishes in the medium gloss range. In fact the test is so popular that many users think that they can use it for all ranges of specular gloss. Unfortunately, however, it cannot be used for measuring high and low gloss.

The new test for distinctness-of-image gloss and the ASTM 20-deg specular gloss test are generally used to measure high gloss. However, high gloss materials are hard to measure by the 20-deg method because of the high degree of flatness and accurate positioning required in order to direct the reflected beam into the small receptor window.

The ASTM 85-deg test can be used for measuring low gloss. The 85-deg geometry is

hard to build into an instrument but the problem can be eliminated through good design.

Actually, some observers feel that there may not be much point in making highly precise measurements of gloss. Gloss cannot be measured as precisely as color and reflectance. It is a phenomenon of the skin of a material and thus tends to be quite variable from point to point and changes with the condition of surface preparation. Thus, gloss measurements of high precision are impossible, and even if they could be made they would probably be meaningless.

Texture and finish: standards are needed

Comparatively little can be said about the measurement of texture and finish for the simple reason that comparatively little work has been done in this field. This is surprising because texture and finish are quite important in almost all products.

Outside of the standard mechanical tests such as the Profilometer and Brush analyzer tests there is no standard equipment available for measuring texture and finish. Profilometer tests are quite valuable for measuring surface roughness; however, they cannot be used for appearance measurements because the results they give often do not correlate with the way a surface looks.

There are very few industry standards for specifying texture and finish, particularly mechanical finishes. For example, one company's No. 4 mechanical finish may be different from another company's No. 4 finish. It would appear that more industry cooperation is needed.

Work is now proceeding at our company on equipment that we hope will provide meaningful measurements of texture and finish. This equipment scans light (both specular and diffuse) reflected by the surface from a small spot of incident light. It analyzes the resulting a.c. signals for both amplitude and slope. The amplitude shows brightness contrasts, and the slope (which is obtained by using high frequency band pass filters) shows pattern sharpness.

It is believed that the resulting data on uniformity in gloss and reflectance will be translatable or convertible to texture. Also, the measure of reflectance uniformity is expected to be useful for controlling the uniformity of printing inks, paper and the like, and in establishing standards of fabric wrinkling.

Little Work on Measuring Appearance of Metals

Although a significant amount of work has been done on rating the appearance of nonmetallic materials, almost nothing has been done on standardized optical methods for measuring the appearance properties of metallic surfaces. This is surprising because the appearance of metals is extremely important in many designs, particularly automobile trim, household appliances, builder's hardware and costume jewelry.

In general, the tests developed for measuring the appearance of nonmetallic surfaces cannot be used on metallic surfaces. This stems from the fact that metallic reflectance is chiefly specular while nonmetallic reflectance is chiefly diffuse. Metallic brightness is an important attribute of metal surfaces but few technologists understand its character. As far as the writer can tell, it is closely associated with freedom from diffuse and semi-diffuse reflectance.

Investigations to date show that the colors of metallic surfaces can be measured by established methods, provided that specularly reflected light is collected for measurement. Also, goniophotometric methods can be used to evaluate geometric distributions of reflected light, and in a few cases these have already shown that useful optical methods can be developed to measure metallic appearance. The relationship between geometric distributions of reflected light and surface appearance is frequently complicated and unrecognized.

The American Society for Testing Materials (ASTM), and particularly its Committee E-12 on Appearance, has been aware of these problems for many years. To date, there has been little financial support for investigating ways to measure the appearance properties of metals. However, a breakthrough has recently been made with the formation of a problem task group within Committee E-12 whose job it will be to prepare standard procedures for measuring the color and gloss of anodized, high-silicon architectural aluminum alloys, and both colored and unfinished aluminum surfaces.

...magnetic properties...

by GEORGE J. FALKENBACH,
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Battelle Memorial Institute

The growth of electrical and electronic applications for materials has been so immense that the work of evaluation has tended to split into distinct and specialized areas corresponding to the electrical functions of the material. Tests for magnetic materials are old and well established, but the need for greater accuracy and speed are resulting in the development of more refined laboratory equipment and more rapid production line equipment. And the increasing severity of environmental conditions makes it likely that still more advanced evaluation procedures will have to be developed.

■ In studying magnetic materials we are usually interested in evaluating two types of properties: intrinsic and secondary properties. The physicist is usually interested in intrinsic properties such as magnetization and anistropy. The designer or engineer, however, is usually concerned with how a material will behave in actual service, and thus he is liable to be more concerned with secondary properties such as permeability, coercive force and losses.

In recent years a great number of special tests and equipment have been developed to make quick and accurate measurement of these properties, both in the laboratory and on the production line. Let's look at them briefly.

Accuracy and convenience

▸ We now have rotating coil fluxmeters (which develop an a.c. voltage proportional to magnetic field) that are accurate to ±0.1%. Even higher accuracy, ±0.01%, can be obtained with recently developed fluxmeters operating on NMR (nuclear magnetic resonance) principles. These fluxmeters are also noted for their ability to control a magnetic field to great accuracy and for their use in studying homogeneity.

▸ Gaussmeters based on the Hall Effect are now capable of an accuracy of ±1% (of the reading, not full scale) from hundredths of a gauss to 10,000 gauss, and somewhat less accuracy to 30,000 gauss. Users also like them because of their mobility and transportability; several battery-operated, self-contained models are now available. Furthermore, they lend themselves to measuring both transverse and axial fields. In many ways the application for these versatile gaussmeters seems to be limited only by the

imagination of the user.

▸ We are now obtaining higher accuracy with new permeameters that can measure magnetizing forces up to 300 oersteds to within ±1%, a significant improvement over older models. A further advantage of the newer models is that they require less test material to provide more meaningful data.

▸ A sensitive field detector (magnetometer) operating on the fluxgate principle can make accurate masurements of field strength from below 0.01 oersted to about 10 oersteds.

▸ A recording torque magnetometer provides an accuracy of ±1%, yet is simple to use and inexpensive.

▸ A magnetic field measuring device that uses ultrasonic techniques permits the use of sampling areas 1/100 that of the smallest Hall effect probe with an accuracy of about ±5%. It is still experimental.

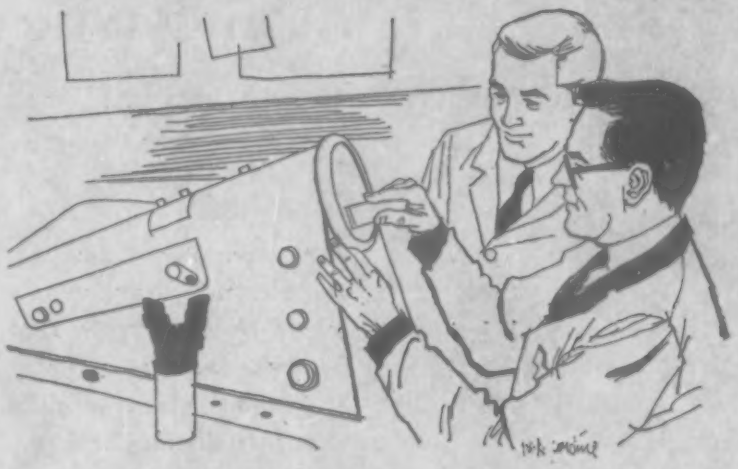
High frequencies

Special techniques and equipment are also required for accurately measuring magnetic properties at high frequencies. The Q-meter works well (the magnetic material is evaluated by using it as a core in a resonant circuit) in the 100 kc to 10 mc range. For higher frequencies, however, three other tests have been developed:

10 to 1000 mc—A small specimen can be evaluated in a coaxial resonator.

50 to 3000 mc—Thin specimens can be evaluated in a coaxial line to provide impedance measurements that can be used to derive magnetic properties.

Above 3000 mc—Specimens can be evaluated in a waveguide instead of a coaxial line, or in a cavity resonator.



Better production tests

Unlike some products, many magnetic devices must be constantly checked during production. This means that tests made on the production line must be easy to use and not interfere with production, as well as being accurate and inexpensive. Spurred by these needs, designers are constantly improving production test equipment. For example:

▸ Practical, low cost hysteresigraphs that will provide rapid and permanent records of B-H loops are continuously being developed. They can record static as well as dynamic hysteresis loops up to several kilocycles.

▸ A recently developed core tester can test a complete memory system and will rapidly detect, count and locate defective memory cores. Less complex, but effective in its own right, is a recently developed test jig that is simple and precise and can be used with standard test equipment.

▸ An advanced magnetic tape tester can detect tape defects as small as one bit length in a packing density of over 1000 bits per inch.

Extreme environments

The extreme environments imposed on many of today's magnetic devices means that we will have to have more tests for evaluating magnetic materials under conditions of high temperature, nuclear irradiation and shock and vibration. Such data are needed because most metallic core materials show appreciable property changes both after irradiation as well as at temperatures just below the Curie point. (Properties of most permanent magnet materials, on the other hand, do suffer little under extreme environments.)

Very little information is available on the effects of combined environments. However, much more data should be forthcoming from government sponsored research.

...dielectric properties...

by K. N. MATHES,
General Engineering Laboratory,
General Electric Co.

Tests for dielectric properties are straightforward; today's principal effort is to determine how well insulating materials maintain their dielectric properties under a variety of hostile service conditions, including heat, cold, stress, solvents and radiation. As in other areas of environmental testing, a major problem is to develop short-time tests that reliably simulate the effects of long-time service. Meanwhile, it is important to look with a critical eye at data obtained in tests that may have little to do with the kind of service we contemplate.

■ In evaluating the properties of insulation materials it immediately becomes apparent that their dielectric properties cannot be divorced from their physical, mechanical and environmental properties. In most cases these properties are interdependent.

Flexible insulation tubing, for example, must retain flexibility at extremely cold temperatures, yet not cut through at high temperatures. An impregnating resin must be fluid enough to penetrate deeply and completely, yet not run back out and leave voids. And a magnet wire enamel must provide a tough coating that is as thin as possible.

These examples are cited to show that although dielectric properties *per se* are important, in many cases they are secondary to, and can be drastically affected by, mechanical, physical and environmental properties. In this article, therefore, we shall be concerned primarily with combined property data.

Tests can be confusing

Much confusion surrounds the purpose of tests on electrical insulation materials. Some of this confusion stems from the fact that in testing and evaluating insulation materials we are faced not only with diverse application requirements but also by an exceedingly large number of materials. Nevertheless, we can separate insulating tests into four general types:

1. Materials research evaluations.
2. Manufacturing control tests.
3. Property identity tests made by the materials producer for the end user.
4. End-use, application tests.

Unfortunately, it is often difficult to set up clear lines of demarcation between these tests. For example, the pro-

ducer of an insulation material may quote values of short-time tensile or electric strength to gain acceptance for his material in a new application, but in reality such values may only serve to identify the material and may not have much bearing on needed application properties.

It is also unfortunate that some tests seem to have been developed simply because they are simple and short, the philosophy apparently being that "something is better than nothing." In truth, however, something is not "better than nothing" if the "something" gives the wrong result or interpretation.

Better 'end-use' data

Of all the insulation tests, probably most important are the end-use or application tests. Such tests are designed to determine:

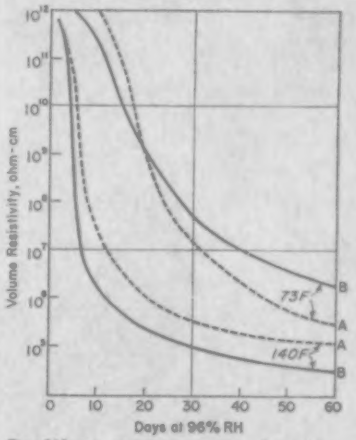
- Mechanical, physical or electrical changes under short-time exposure to extreme conditions (e.g., softening at high temperatures).
- Degradation due to thermal, voltage, mechanical or radiation aging.

These tests are complicated by the fact that in many cases they involve combined effects. Thus, as one property changes it may cause another property to change (e.g., thermal aging combined with voltage aging). The problem is so complex that some engineers believe that insulation materials by themselves cannot be evaluated and that only performance tests on completed devices are significant. This, of course, is an extreme attitude; many problems remain but they are not unsolvable.

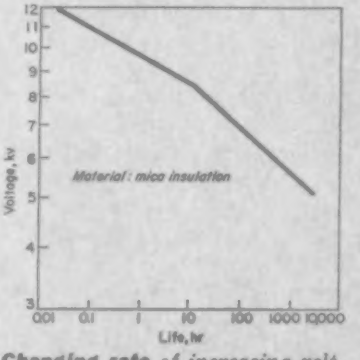
Property trends must be evaluated over a range of exposure conditions — curves rather than single point data. Certainly such data is more difficult to obtain, disseminate and interpret than single point data which can be glibly quoted by an unskilled salesman.

Several material producers, notably those supplying plastics insulations, have recognized this need and now supply complete information on properties such as modulus, strength, and elongation to failure, as well as electrical resistance, power factor, etc., as a function of temperature. Curves of power factor vs frequency are also common.

Of course, insulating materials suppliers will usually supply such expensive data only if there is a demand for it. Users should recognize and make known their needs, since it is usually less expensive for the manufacturer to make the needed tests rather than have each user work the data out for himself.



***Positions may reverse** when temperature is raised to accelerate humidity aging. At 73 F curves cross; at 140 F curves are roughly parallel.*



***Changing rate** of increasing voltage provides accelerated voltage-aging data on insulators.*

We need more data on aging properties

There is a serious lack of information on the effect of time on insulating materials. For example, impulse voltages of a few microseconds duration can have widely different effects on different kinds of insulation. Short-time data such as these are often difficult to obtain experimentally.

We also encounter many problems in obtaining long-time aging data. Many of these tests are costly because of the excessively long time required to provide useful data. Sometimes the data is developed too late for it to be of much use.

Much effort is being devoted to developing new and improved aging tests, particularly for determining the single and combined effects of thermal,

humidity and voltage aging.

Thermal aging. Over the past 15 years we have made considerable progress in accelerating thermal aging tests by using the chemical reaction rate theory. However, these tests raise both theoretical and practical difficulties. For example:

- It is always questionable whether we can extrapolate short-time test data obtained at a high temperature to find the expected life of insulation at lower temperatures. Insulation life at lower temperature may depend upon a different mechanism (e.g., a different activation energy) than that encountered at higher temperature.
- It is difficult to select appropriate end-points for thermal aging tests.
- Thermal aging tests are hard to duplicate closely in different laboratories.

Humidity aging. Many different approaches have been tried in making accelerated humidity aging tests on insulation materials. We have made useful comparisons between materials by raising temperature to accelerate the aging. However, we should recognize that higher temperatures may reverse the order of comparison as time increases (see first graph).

Even in humidity tests made at normal temperatures it can be misleading to make measurements for only 48 or 96 hr at high relative humidity, especially when trying to find the effect of long-term tropical conditions. In such cases it may be advisable to use short cycles of humidity which provide a cumulative effect more like continuous, long-time exposure.

High voltage stress aging. High voltage can also cause slow degradation of insulation materials. In the past we have customarily determined the voltage life of insulation materials and systems by using a series of tests at increasing voltage levels just above the corona starting voltage. However, such programs are plagued by unexpectedly early failures as well as individual tests that never seem to cause failure (so-called "hangers-on").

We can minimize these problems by steadily increasing voltage stress to produce failure in a much narrower band of time. Thus, different failure times can be produced by changing the rate of increasing voltage (see second graph). As with thermal aging tests, the different slopes obtained at different stress levels may make it difficult to extrapolate the data. Nevertheless, the results can be of great value. This approach of increasing voltage stress can also be used to determine the electrical tracking characteristics of insulation surfaces under different conditions of surface contamination.

Similarly, we have recently learned that a technique of slowly increasing mechanical or physical stress can be used to determine long-time deterioration. It has been successful in finding the fatigue strength of plastics, and similar work is underway on other materials.

Normal voltage aging. Many differences of opinion have arisen over current studies of normal voltage aging. For example, some European investigators are stressing tests using needle electrodes which emphasize corona erosion; others are using a corona cell with a glass or mica barrier which emphasizes the chemical degradation of corona. And in the United States an ASTM test has been developed using a direct electrode (½-in. dia) test for voltage endurance. This is an intermediate test: both erosion and chemical effects are involved.

Perplexing problems also arise when we study combined stresses, such as the effects of moisture and temperature on voltage aging. It is particularly difficult to extrapolate results from combined aging tests. In general, it appears that we should vary only one stress at a time if we are to extrapolate data. Also, the static stress should not exceed that expected in service.

Many interesting investigations have stemmed from work by Howard in England who found that an increase in frequency produces a linear acceleration in the voltage aging characteristics of polyethylene-insulated cable. Many investigators now tentatively believe that voltage aging can be accelerated by a factor of 100 by increasing the test frequency from 60 to 6000 cycles. There seems to be good agreement for low loss materials such as polyethylene which fail by corona erosion. On the other hand, voltage failures are not linear over a wide range of frequencies for high loss materials or for certain composites.

. . . impurities, other semiconductor properties

by D. K. HARTMAN
and R. E. HYSELL,
Semiconductor Products Dept.,
General Electric Co.

The growth of solid state devices has brought with it a new field of materials evaluation of interest to engineers and designers. The kind of procedures discussed in this article, now of interest only to engineers in certain portions of the electronic and electrical industries, may become of increasing interest to engineers in many other industries. For the design of materials continually becomes more closely related to their inherent structure.

■ The comparatively new science of semiconductors has brought about a whole new series of tests and equipment for evaluating materials. Because of the important effect that crystal purity has on performance many of these tests have been especially designed to detect and measure impurities. Not to be overlooked, however, are the new tests that have had to be devised for measuring crystal structure and orientation, as well as electrical properties.

All of these variables are by no means easy to measure and control. However, we are achieving notable success in developing and applying methods for evaluating semiconductor materials in large production quantities.

Measuring Impurities

In producing semiconductor devices we need to have some means of detecting and measuring the two types of impurities: primary and contamination. Contamination impurities are those present in the original source material or accidentally introduced during crystal growth and processing; primary impurities are those intentionally added to the material to adjust its electrical properties to meet design requirements. Concentration of these dopant materials can range as small as parts per billion in materials intended for high voltage rectifiers to major fractions of 1% in materials for tunnel diodes.

Electrical properties can provide important information on the concentration and mobility of majority charge carriers, whether they be holes or electrons. The two primary electrical measurements used in evaluating semiconductor materials are resistivity and the Hall constant. Measuring resistivity as a function of position is useful in checking crystal homogeneity. And the Hall Effect measurement is important because it determines conductivity type. Sometimes, however, this property can be determined more simply by measuring the polarity of the thermoelectric coefficient.

In addition, we can also measure mobility as a function of temperature. In materials in which contamination impurity content is high this measurement provides an estimate of total impurity concentration. It is particularly useful with compound semiconductors.

Another useful parameter is carrier lifetime. Lifetime is one of the most sensitive measures of crystal purity and perfection and is quite important in designing semiconductor devices. Although the lifetime of germanium and silicon crystals is high enough to exceed requirements, this is not the case with compound semiconductor materials which have low lifetimes. These low lifetimes are difficult to measure and the results are often obscured by trapping phenomena.

Lifetime measurements of germanium and silicon can be made by a standard technique such as direct observation of the transient decay of photoconductivity. Less direct methods must be used with short lifetime materials. Some success has been obtained with a technique based on the photomagnetoelectric effect. Other tests are even more indirect; for example, fabricating p-n junctions in a material and analyzing its junction characteristics.

Optical measurements of semiconductor materials can also be valuable. The measurement of photoconductive spec-

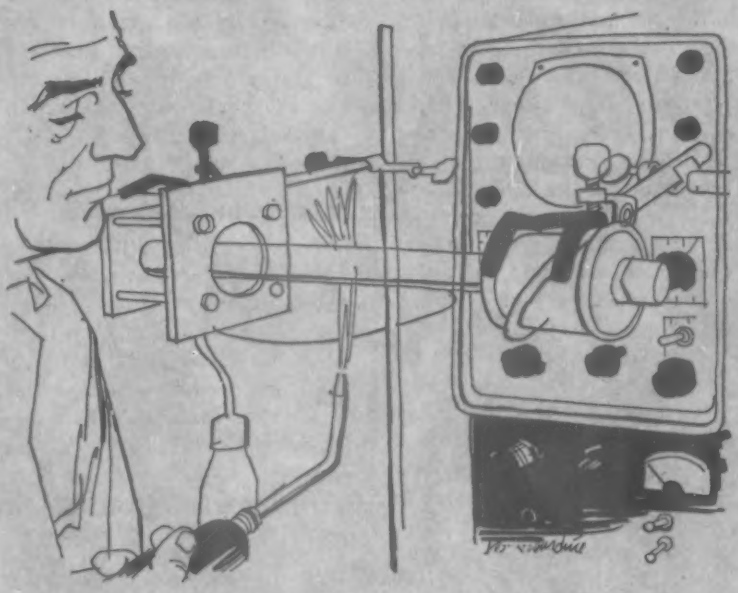
tral response, for example, has been widely used for studying the basic properties of solid state materials.

We can also use absorption measurements with semiconductors because they are transparent in the infrared range. These measurements have proved particularly useful in detecting oxygen impurities which, in the case of germanium and silicon, can be electrically inactive and not detectable by electrical measurement.

Another valuable optical test is infrared absorption which can be used as a basis for contactless measurement of carrier concentration in heavily doped materials.

Physical measurements such as electron and x-ray diffraction are also a good tool for evaluating semiconductor materials. Electron diffraction is particularly useful in studying the crystalline properties of surface films and layers. X-ray diffraction has been found useful in studying crystal structure, orientation and perfection. Diffraction line width data from rocking curves are helpful in detecting gross impurities such as excessive dislocation density or work damage. Also, test modifications based on the Berg-Barrett technique can provide a visible picture of crystal imperfections.

Metallographic procedures for semiconductor materials are well developed, and many recipes for chemical stains and etches are now available. These etch treatments make it possible to obtain a quantitative measurement of dislocation density, which is the most significant factor in specifying crystal perfection.



Minimizing tests

Semiconductor manufacturers cannot afford to make all of the measurements that could be made. Today the semiconductor industry is extremely competitive (over 100 manufacturers) and costs have to be kept down. This is not easy, especially in the face of user demands that tight specifications be held even in large production quantities.

Nevertheless, manufacturers have been able to meet rigid specifications with a limited number of tests such as:

1. Orienting the material and making a statistical evaluation of its structure.
2. Measuring conductivity type, lifetime and resistivity.

Let's look at these possibilities in a little more detail:

Controlling orientation and structure of semiconductor materials has become extremely critical. Alloy junctions, for example, must be parallel to the surface to insure reliability. Today's semiconductor devices frequently have to do with dimensions on the order of microns.

For high frequency devices with small dimensions, the industry has found that the orientation of the material must be held to better than ±5 min of arc. And in development devices, designers are trying to hold orientation to tolerances as low as ±1 min. However, for less sophisticated devices orientations of ±2 deg are adequate.

In semiconductors whose size is in the micron range, properties are related to the structure of the material, particularly to dislocation density. Such de-

vices require statistical sampling of materials to insure that dislocation density does not exceed specifications. In larger devices, however, proper growth procedures can keep crystalline structures within acceptable limits. In such devices it is only necessary to monitor materials on a quality control basis, provided that good crystal growing procedures are observed.

Conductivity and lifetime—These properties can be measured on a spotcheck basis. The science of growing crystals is now sufficiently understood and techniques are exact enough so that conductivity type need only be measured on a casual basis. Furthermore, materials producers have found that they can control the lifetime of a material by using good crystal growing practices and keeping the environment clean. Thus, lifetime measurement of every crystal is not necessary; measuring statistically selected samples has proved sufficient.

Resistivity—In earlier days, semiconductor users were happy if resistivity limits were within ±50%. Continued progress, however, has reduced this figure to ±10%, and the trend is toward a resistivity spread of only ±5%.

Because of the importance of resistivity measurements it has been necessary to develop very precise equipment. It has also been necessary to derive and apply precise mathematical corrections for sample geometry. Furthermore, because semiconductor resistivity is sensitive to temperature, it has been necessary to hold specimen temperature within ±2°C. Continued advances in the art have resulted in instruments that are accurate to within ±2%, and semiconductor material is being supplied with a ±10% resistivity tolerance.

New problems coming

In light of past history we can expect to find many new problems in evaluating semiconductor materials. For example, with the advent of materials prepared by epitaxial and dendritic techniques it is necessary to work with small physical dimensions which are difficult to handle and which create some unique electrical problems.

Also, with the increased use of compound semiconductors we will be faced with the very severe problems of making short lifetime measurements on a production basis. Furthermore, as we start to use large band gap materials it may be necessary to make some measurements at elevated temperatures.

Acknowledgments and References

Friction Properties, Wear Resistance

The author would like to express his appreciation for the invaluable assistance given him in preparing this article by H. S. Avery and H. Harris of American Brake Shoe Co.'s Research Laboratory; R. H. Read of Armour Research Foundation; and A. C. Webber of Du Pont's Experimental Station.

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SILICONE NEWS

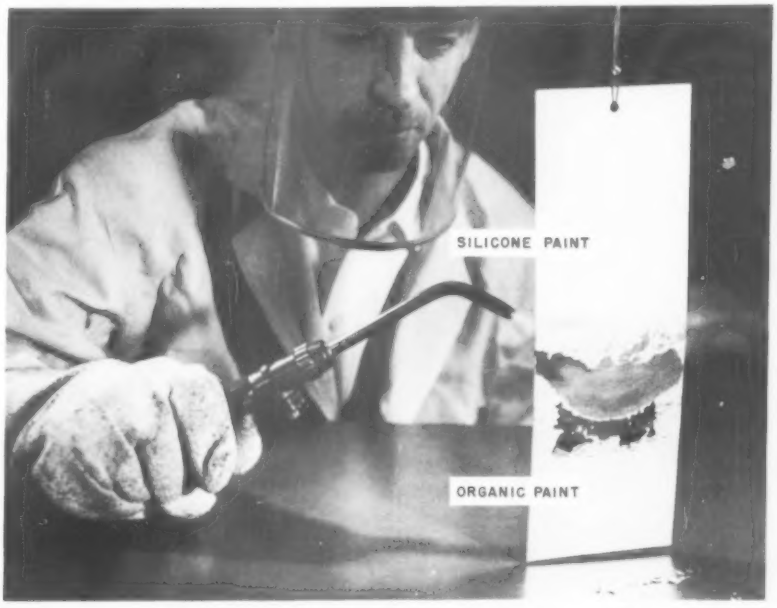
for design and development engineers · No. 83

SHATTERPROOFED WITH SILICONES

One of the most common safety hazards — exploding light bulbs — has been overcome in a new incandescent lamp through the use of silicone adhesives and glass yarns.

Developed and marketed by Duro-Test Corporation, North Bergen, New Jersey, the new lamp — named "Flamescent" — is truly shatterproof. It can be dropped onto a hard surface without exploding into a shower of glass. While in use (and hot) it can be dipped in ice water without danger of flying glass fragments.

Unique application of new *and* old materials gives the lamp this safety-glass ruggedness. The bulb consists of a glass shape wound with *(Cont. pg. 2)*



New Finish For Hot Spots

Metal products of all descriptions can now be made to stay new looking longer even when subjected to hot operating temperatures or to the deteriorating effects of weathering. How? By using protective coatings and finishes formulated with Dow Corning silicone resins.

Colored product finishes based on these semi-inorganic resins won't crack or blister even up to temperatures as high as 600 F. Gloss and color are retained even though constantly exposed to sunlight or corrosive atmospheres. Result — longer life, and increased customer satisfaction.

New silicone-alkyd baking enamels combine ease of application with flexibility and toughness. Using these enamels, it's frequently practical to paint-before-forming metal parts. Baking cycles are consistent with standard painting practices.

Full range of colors, too. Silicone-based paints can be pigmented almost any hue.

Available now from many paint manufacturers, silicone-based paints could help make important changes in your quality and profit picture. For more information and names of suppliers, circle . . **No. 242**

Paint based on new Dow Corning resin takes a 180° bend on a ¼" mandrel without crazing, checking, or peeling.

Reproduces Fine Detail

The making of what are believed to be the most accurate models of the moon in existence today was given a big boost by Silastic® RTV, the fluid silicone rubber that cures at room temperature.

By pouring Silastic RTV over his original, painstakingly constructed model, Mr. William Benton, "the moon man", obtained flexible and dimensionally stable molds that perfectly duplicate the extremely fine details of the original. Polyester resins are cast in the RTV molds to make more of these accurate moon models.

Silastic RTV is easy to use. Simply mix it with a catalyst and pour. The mix flows freely, filling every hairline. After a few hours at *room temperature*, you have a flexible silicone rubber mold that strips readily. You're ready to start casting!

Reproduction: Benton model of the moon

Flexible molds for producing prototype parts in plaster, plastics, waxes or low melt alloys are quick and inexpensive with Silastic RTV. Circle . . . . . **No. 241**

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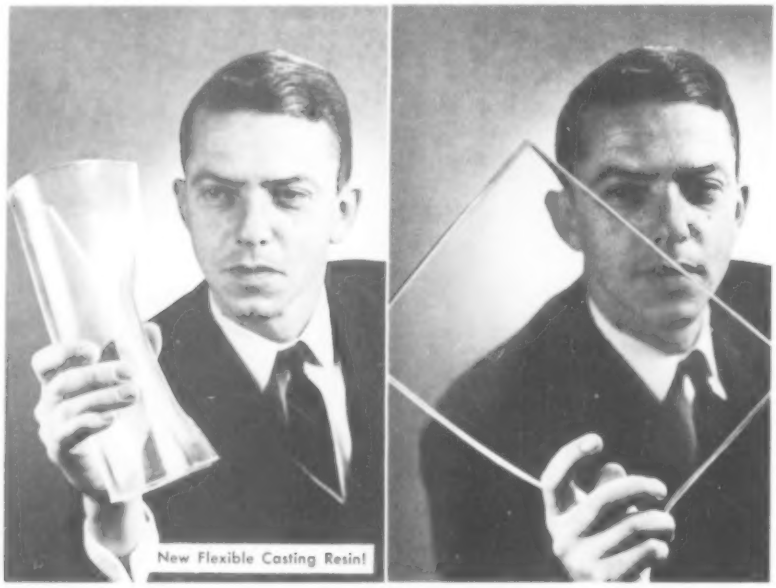

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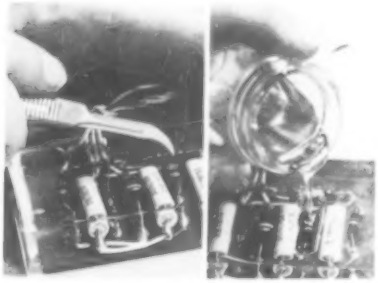
. . . to investigate a unique new silicone resin that cures to form a tough, transparent mass. Named Sylgard® 182, this new solventless silicone resin is supplied as an almost colorless liquid. After blending with its curing agent, it's a simple matter to pour it in place.



Even in totally confined enclosures, Sylgard 182 cures to a flexible and transparent material having outstanding dielectric properties and good moisture resistance from —100 to 400 F. On the Shore A Scale, hardness of Sylgard 182 is approximately 40; elongation is in the range of 100%. Tensile strength is in the range of 800 to 1000 psi.

Curing time for Sylgard 182 Resin can be varied by changing the curing temperature. At 150 C, it cures in 15 minutes; at 65 C, four hours; at 25 C, three days. Neither the resin nor its curing agent is toxic to the skin. No toxic fumes are given off during mixing or curing.

⇦ Electronic components and circuits encapsulated in Sylgard 182 Resin are clearly visible, simplifying replacement or repair procedures. The cured resin can be cut away with a sharp knife to permit repair or replacement of defective components. New resin poured over the repaired area adheres to the existing cured material, restoring the encapsulant to the original condition.

Keep in mind that while this new material exhibits some rubber-like properties, it is a solventless silicone resin, not a rubber. For more data and information about Sylgard 182, circle . . . . . *No. 243*

new literature on silicones

Silicones in Appliances can give that extra edge for extra sales. This colorful booklet tells where and how silicones are being designed into appliances to give more efficient and reliable performance. Illustrations show how planning around silicones can make good products better. *No. 245*

Space Age Silicones are described in thirty typical application stories. Utilization of silicone compounds, fluids, lubricants, protective coatings, rubbers, resins, potting materials and sealants are illustrated for your consideration. This valuable brochure offers solutions to many problems encountered in designing space age aircraft and ground support equipment. *No. 246*

You And The Silicones — a 30-minute, full color movie lets you see silicones in action. It's an all-encompassing, dramatic documentation of designers' adaptations of these versatile engineering materials in different applications. For information about arranging for a free showing, request . . . . . *No. 247*

LIGHT BULB *(Continued)*

Fiberglas yarn. The glass and yarn are bonded into a single unit with a rubbery Dow Corning silicone adhesive. Several materials were tested but only the silicone adhesive remained transparent and resilient despite long, continuous exposure to the heat of the lamp.

While the Flamescent derives its name from the warm, flame-like glow it casts, its lumen output is actually higher than that of any other processed bulb. It is a glareless bulb and lasts at least 3 times longer than conventional lamps.

Available in standard sizes, the Flamescent with its weatherproof features is ideal for yard and outside display lighting. Duro-Test also recommends the new bulb for use in all types of industrial and commercial fixtures where the bulb may come in contact with flying sparks, welding slag, hot solder, water, and many other attacking conditions. *No. 244*

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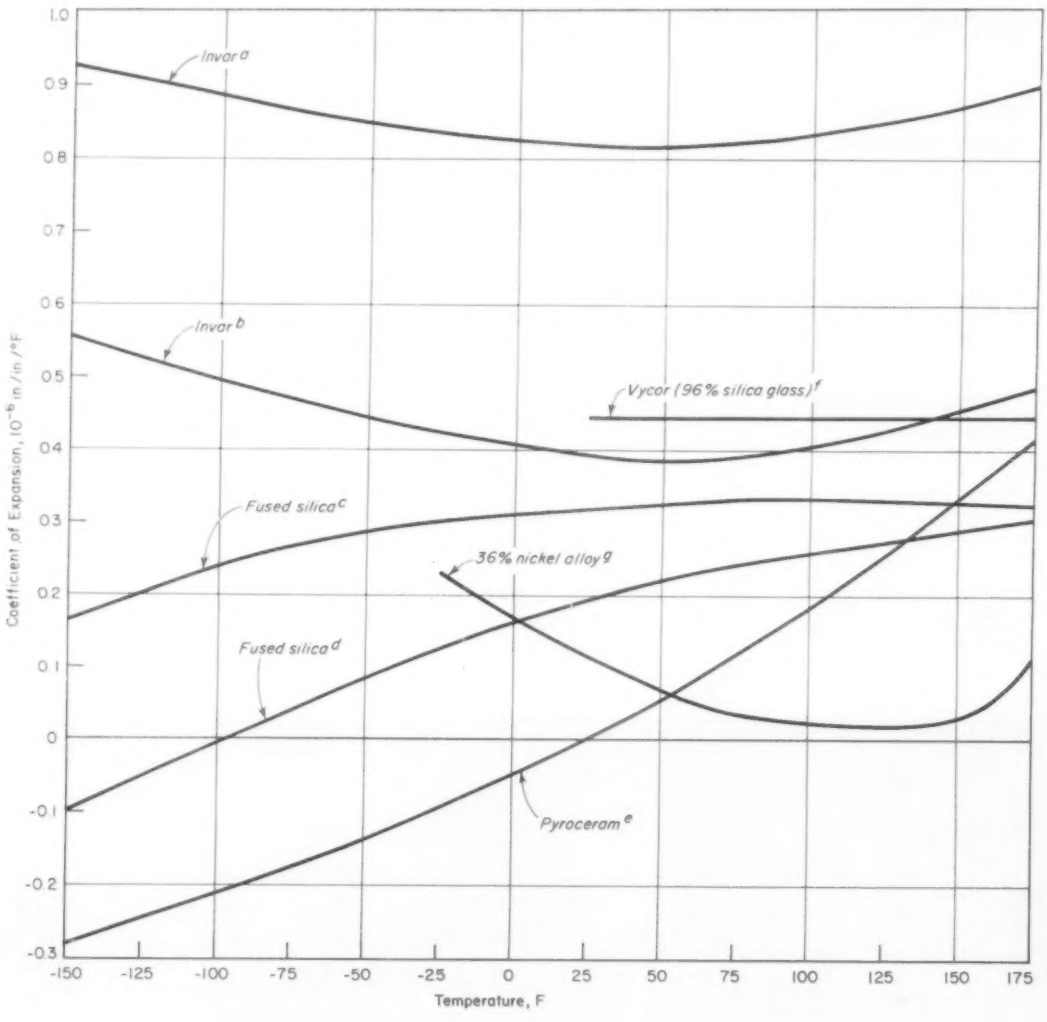
Coefficient of Expansion vs Temperature for Low Expansion Materials

FILE FACTS

This graph shows the variation of coefficient of expansion with temperature for several low expansion materials. It is intended as an aid in designing precision optical instruments where consideration must be given to the differential expansion between glass elements and their housings. Such allowance is necessary to minimize movement and de-focusing which occurs due to changes in length with temperature.

Prepared by Charles Eumarian, Mechanical Div., General Mills, Inc.



[a] Annealed for 1 hr at 1550 F; air cooled. International Nickel Co.
[b] Cold drawn 50%. Annealed for 2 hr at 650 F; Air cooled.
[c] Code 7940, Corning Glass Works.
[d] National Bureau of Standards.
[e] Code 9608, Corning Glass Works.
[f] Corning Glass Works.
[g] Alloy LA-685, General Communications Co.

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Price of copper has been increased 2¢ per lb to 31¢ by the major producers and smelters. Last winter copper prices were reduced 1¢ per lb to 29¢ (M/DE, Feb '61, p 129).

Availability of two new refractory materials—hexaboron silicide and tetraboron silicide—has been announced by Allis-Chalmers Mfg. Co. The two silicides are sold as black, microcrystalline, free-flowing powders. Prices range from $35 to $50 per lb. See p 9 for more details on the two materials.

A new supplier of beryllium metal is Beryllium Metals & Chemicals Corp., formed by Alloyd Corp. and Lithium Corp. of America. The new company will do beryllium research and produce high purity metal and beryllium chemicals.

A price cut on beryllium metal powders has been announced by Brush Beryllium Co. Price of virgin powder has been reduced from $71 to $62.50 and blended powder from $64 to $54 per lb in lots of 20,000 lb or more.

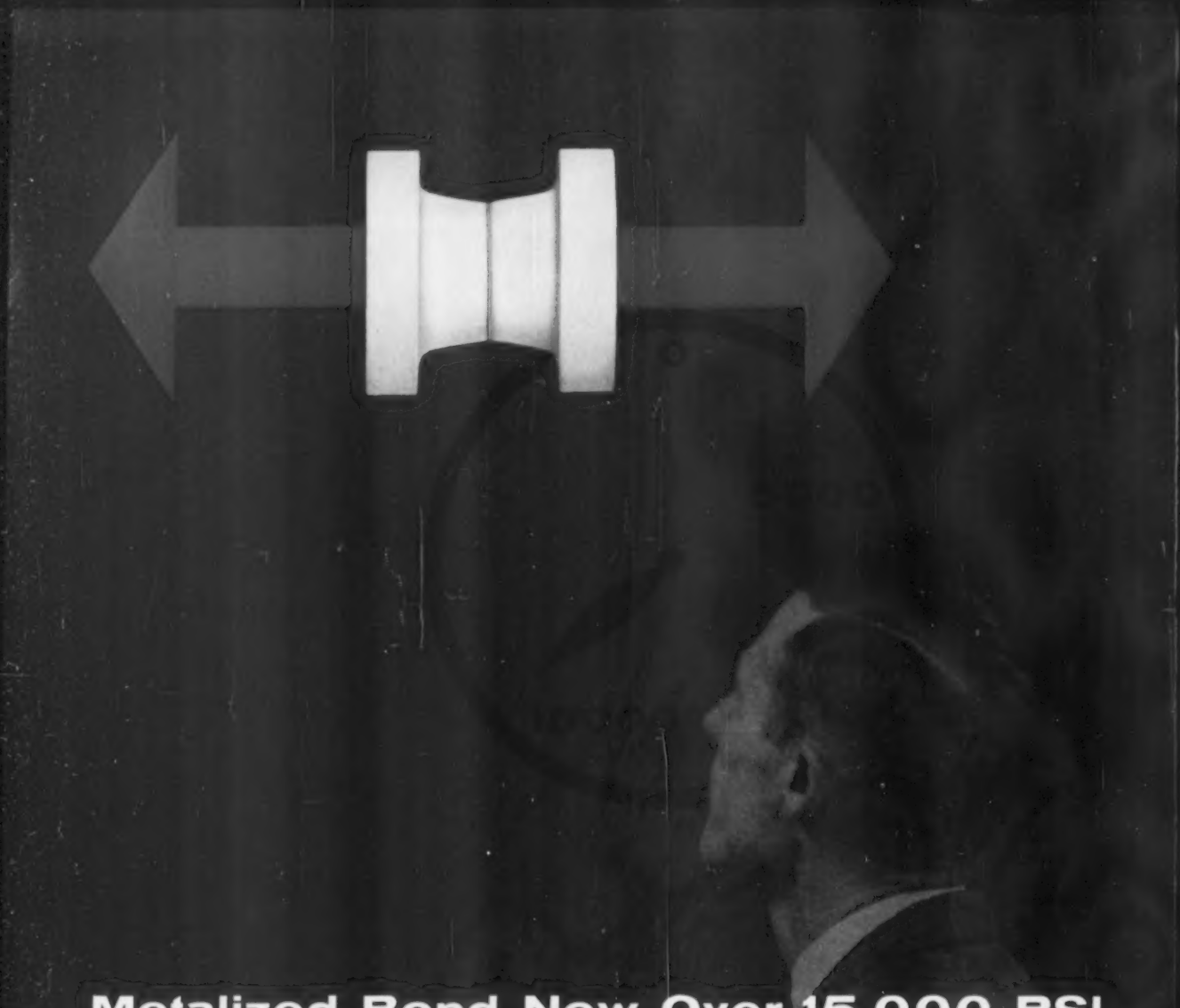
Price reductions on polyester and nylon fibers have been put into effect by Du Pont. Price cuts for Dacron polyester fibers range from 7 to 17¢ per lb and nylon from 4 to 15¢ per lb.

Commercial production of columbium mill products has been announced by Du Pont. A new plant in Baltimore is producing the metal and its alloys in the form of sheet, strip, plate, bars, tubes and other shapes. Price for the mill products averages $60 per lb. The new plant is designed so that tantalum, tungsten and molybdenum can be produced in the future.

A new supplier of polypropylene is W. R. Grace & Co. The company will market polypropylene produced in a new plant being built at Neal, W. Va. by Novamont Corp., a subsidiary of Montecatini. The plant will have an initial capacity of 25 million pounds and will go on stream the third quarter of this year. Chemore Corp., Montecatini's U. S. representative, will also sell polypropylene produced at the plant.

Price of tellurium has been increased $1.25 per lb by American Smelting & Refining Co. and American Metal Climax. Other major producers are expected to follow with similar price increases. New price is $5.25 per lb for commercial grade (99.7% pure).

Production of nine high purity metals—antimony, arsenic, bismuth, cadmium, gold, indium, selenium, silver and tellurium—has been increased and put on a commercial scale by American Smelting & Refining Co. Purity of the metals is more than 99.999%.



Metalized Bond Now Over 15,000 PSI

Advanced metalizing and brazing techniques at Coors now produce bond strengths better than 15,000 psi. Test parts, as shown above, are being considered for standard ceramic-to-metal test specimens by ASTM. These Coors test parts are run with each group of customer parts to guarantee specifications. Coors is presently metalizing and brazing parts of large mass and complex design, using these high strength techniques. For the newest techniques in high temperature, high strength ceramic-to-metal assemblies, write for Technical Data Sheet No. 0500, "How Ceramic-To-Metal Seals Are Made"—or call your nearest Coors Regional Sales Manager: WEST COAST, *William S. Smith, Jr., EM 6-8129, Redwood City, Calif.;* MIDWEST, *John E. Marozeck, FR 2-7100, Chicago, Ill.;* CENTRAL, *Donald Dobbins, GL 4-9638, Canton, Ohio;* EAST COAST, *John J. McManus, MA 7-3996, Manhasset, N.Y.;* NEW ENGLAND, *Warren G. McDonald, FR 4-0663, Schenectady, N.Y.;* SOUTHWEST, *Kenneth R. Lundy, DA 7-5716, Dallas, Texas;* SOUTHWEST, *William H. Ramsey, UN 4-6369, Houston, Texas.*

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DETAIL OF METALIZED AREAS ON TERMINAL

(cont'd from p 124)

causes wide openings that allow gases or liquids to attack that much deeper in the wood. Splits or shakes should be avoided in good construction.

Checks, or minor splits, caused by drying usually close up when moisture is present. They are usually not detrimental unless they are excessively deep and wide.

Resin-impregnated woods

Impregnants based on a variety of synthetic resin systems, promise substantial improvements in life of wood tanks and equipment. Resins are applied by a vacuum and pressure process and then cured, making the wood resistant to hot and highly corrosive chemicals that are detrimental to wood in its natural state.

For example, Arrow Tank has developed an acid-modified phenolic system in an alcohol and water medium, called the "KO" series. The impregnated wood is baked at 150-160 F to cure the resin. Blocks of California redwood treated in this way were immersed in 25% sulfuric acid at 120 F and agitated violently for 58 hr, then permitted to stand for 336 hr. The treated block showed no shredding, no loss of wood fiber, no swelling and only slight softening. An untreated block subjected to the same treatment showed loss of wood fiber and severe shredding.

Other impregnants such as monomeric solutions of furfuryl alcohol with an incorporated catalyst are used with considerable success. Such impregnants thoroughly penetrate the wood cell structure providing excellent chemical resistance.

At present the cost of impregnated lumber is high. Continued research and process development should bring the cost down to a more widely competitive range.

Author's Note

Further information on rules covering grading of lumber can be obtained from the following organizations:

Tidewater red cypress: Southern Cypress Mfg. Assn.
Yellow or deep swamp cypress: National Hardwood Lumbermen's Assn.
Pine: Southern Pine Inspection Bureau
California redwood: California Redwood Assn.
Douglas fir: West Coast Lumbermen's Assn.

This article was adapted from a paper presented at a meeting of Niagara Frontier Section, National Assn. of Corrosion Engineers, May '59.

Quenching Strengthens Copper-Babbitt Bonds

Immediate quenching is said to strengthen the bond between copper and babbitt by reducing the thickness of a tin interface layer that penetrates the eutectic matrix of copper-tin and tin.

Tensile tests of specimens made with this technique broke them in the babbitt, not in the joint, according to S. Rosenbaum, Research and Advanced Development Div., Avco Corp.*

Interface formations studied

The problem of bonding copper to babbitt may be erroneously considered routine because it is the usual soldering procedure to wet copper with tin-rich alloys, Rosenbaum says.

The interface formation was investigated in a series of tests that considered: 1) the effect of varying casting temperature while maintaining a fixed preheat temperature; 2) varying the preheat temperature while holding the casting temperature constant; and 3) increasing the cooling rate.

The procedure was as follows:

* Now chief metallurgist, Engineered Metals Co.

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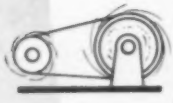


for High-Speed, Unlubricated Uses—In terms of life, maximum speed, and low friction, Stackpole carbon & graphite offer many performance dividends over even more costly self-lubricating bearing and seal ring materials.

Handling Chemicals & Gases—Inert Stackpole carbon & graphite resist attack in all but the most highly oxidizing atmospheres at normal temperatures.

Under Thermal Shock—Stackpole carbon and graphite materials will not spall, crack, melt or seize in difficult refractory applications.

STACKPOLE

Stackpole Carbon Company, St. Marys, Pennsylvania

GRAPHITE BEARINGS & SEAL RINGS • ROCKET NOZZLES • PUMP VANES • VOLTAGE REGULATOR DISCS • GRAPHITE HEATING ELEMENTS • CHEMICAL ANODES • BRUSHES FOR ALL ROTATING ELECTRICAL EQUIPMENT • ELECTRICAL CONTACTS • CERAMIC MAGNETS • FERRITE CORES FIXED & VARIABLE COMPOSITION RESISTORS • SLIDES SWITCHES • and many others.

For more information, turn to Reader Service card, circle No. 359

MATERIALS ENGINEERING & DESIGN

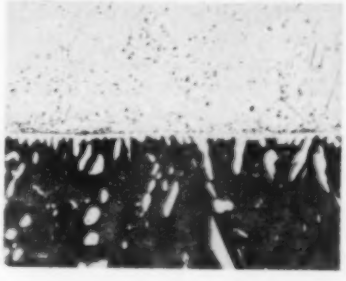
Electrolytic tough pitch copper bars were polished and placed in individual graphite molds. The molds were heated in a furnace until the copper reached the desired preheat temperature. At that time, the bars were tinned and melted babbitt was poured in.

Tensile tests were run on the cooled bars. The casting temperature that produced the strongest air cooled specimen (11,250 psi) was 950 F with a preheat temperature of 500 F. When casting temperature was held at 940 F, preheating at 300 F gave the best result (11,075 psi).

Quenching reduces tin film

It was reasoned that bond strength could probably be increased if the thickness of the interface copper-tin layer could be reduced; and that its thickness was probably influenced by cooling rate, preheat temperature and casting temperature.

In a third test, specimens were preheated and cast at the temperatures (500 F and 875 F, respectively) found to give maximum strength, and then quenched immediately after



***Cross section** of weak copper-to-babbitt bond (top) shows thick tin interface. In strong bond (bottom) the tin film is much thinner. The copper base is shown at the top of both photographs.*

NEW FROM DU PONT...
a thermoplastic "Teflon" film that's easy to fabricate

TEFLON® FEP FILM

New "TEFLON"* FEP-fluorocarbon film has nearly *all* the unique advantages of "TEFLON" TFE with one big plus. It's a true thermoplastic that can be easily formed and sealed. One type of this new film can be applied *with* adhesives, another can be laminated and heat-bonded *without* them.

Here are just some of the advantages of "TEFLON" you get in this new film • Unique antistick and low-friction properties • Chemically inert to practically all known chemicals • Electricals are high (up to 4,000 volts/mil dielectric strength) and *stay* high • Performance stays virtually constant from –250°C. to over 200°C.

"TEFLON" FEP film opens the door to whole new areas of design and product improvement. Mail coupon and start investigating "TEFLON" FEP film for yourself. (Briefly describe the end use you have in mind.)

**Du Pont trademark*

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. . . THROUGH CHEMISTRY

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Job Function_____
Proposed End Use_____

Find out about *cementable* "Teflon" FEB film at the Plastics Show, Booth #1024

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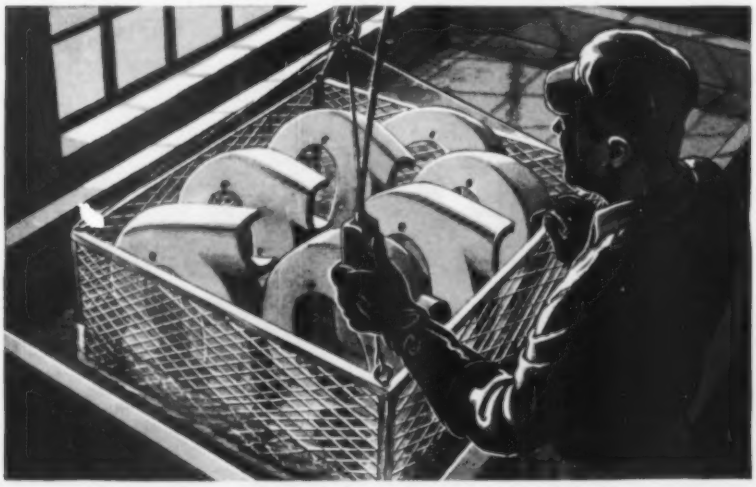
To prevent corrosion and anchor paint on aluminum

ask Oakite

OVER 50 YEARS CLEANING EXPERIENCE • OVER 250 SERVICE MEN • OVER 160 MATERIALS



Protect aluminum at lowest unit cost with CHROMICOAT conversion coatings

Oakite CHROMICOAT is an economy any way you look at it: on the basis of price alone . . . on solution make-up and "mileage"... on the way it blocks corrosion and forms a perfect anchor for paint to keep your customers sold and satisfied.

This is a conversion coating you can depend on. Oakite ChromiCoat protects for hundreds of hours under the ordeal of salt-spray tests . . . and surpasses MIL-C-5541 specs *several times over!*

And the Oakite process is simplicity itself. No control problem. A thin, golden, uniform coating every time.

ChromiCoat is just one of a line of more than 30 Oakite materials designed especially for aluminum. There are etch and non-etch cleaners . . . barrel finishing compounds . . . safe paint strippers . . . forming lubricants.

For more information, ask your local Oakite man or write to Oakite Products, Inc., 45B Rector Street, New York 6, N. Y.

it PAYS to ask Oakite

OAKITE

over 50 Est. 1909 SCIENCE

years' leadership in industrial cleaning

For more information, turn to Reader Service card, circle No. 337

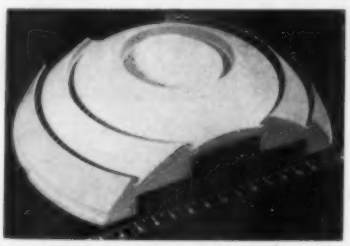
casting. Tensile strengths ranged from 11,090 psi to 12,580 psi with reductions in cross-sectional area from 4.3 to 7.6%. Structures of a strong and a weak bond are compared in the micrographs.

Radar Lens Made from Foam-in-Place Epoxy

A plastics lens that concentrates wideband radar signals in much the same way as a convex glass lens focuses light has been developed for airborne doppler radar systems.

A foam-in-place epoxy resin reinforced with glass fibers and aluminum was developed by the Non-Metallics Section, Manufacturing Research, Republic Aviation Corp., for the lightweight lens. The fibrous glass addition contributes to the strength of the system, and the metal filling is used to control the dielectric constant.

The precisely controlled mixture is foamed in an aluminum mold and cured at 200 F for 14 hrs. After postcuring for 12 days at 250 F, the lens is machined to ±0.005 in. Flatness is held to ±0.002 in., and dielectric constant is held at 2.54 ± 0.1 at 9800 mc. Density is only 15-30 lb per cu ft.



***Radar lens** made from foam-in-place epoxy resin with metal and fibrous glass filler.*

Investment Cast Bracket for Jet Landing Gear

A critical, load-bearing bracket for a jet landing gear is now being investment cast, instead of forged and machined, at a saving of approximately $1000 per part.

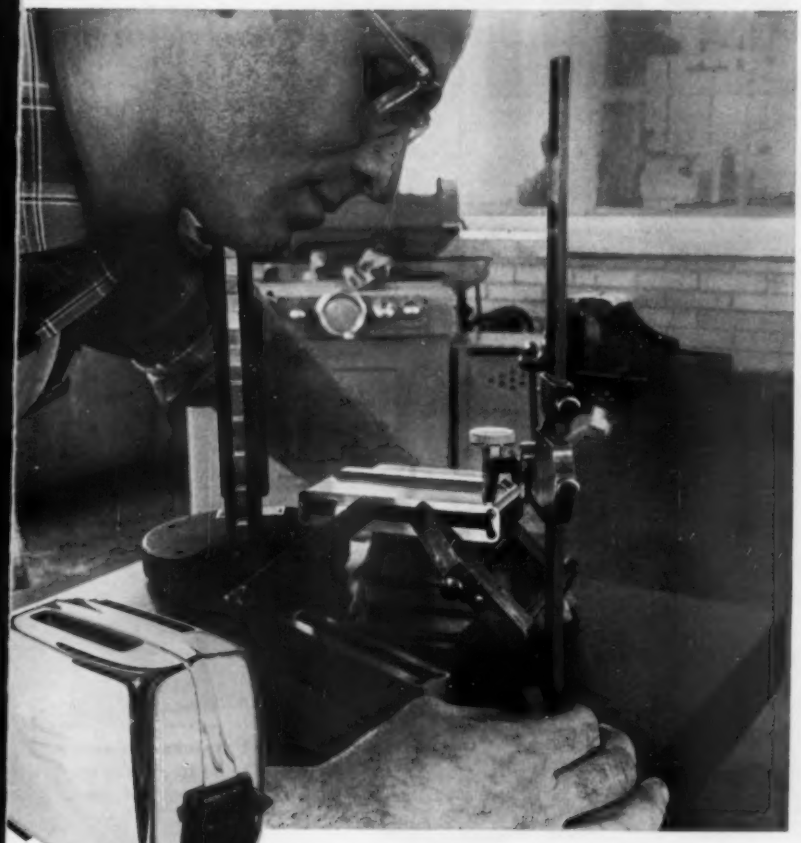
The unit, called an uplock bracket, is attached to the side brace on each

Steel
for Strength
. . . Economy
. . . Versatility

Tool Steel Topics

BETHLEHEM STEEL

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.



Air-4 Blanks and Draws Bread Slots in GE Toaster Shell

This blanking and drawing die, made from Bethlehem Air-4 tool steel, forms bread slots in .030-in. steel sheet for a General Electric automatic toaster. Hardened to Rockwell C 59, the die sections were made by Yarema Bros. Tool & Die Co., Allentown, Pa. They were pleased with Air-4 for two reasons—minimum distortion during heat-treatment, and easy machinability.

Hardens in Air at 1550 F

One of the big advantages of Air-4, Bethlehem's new free-machining medium-alloy tool steel, is its ability to harden in air at low temperature — about 1550 F. Air-4 has exceptional free-machining characteristics because just the right amount of lead has been added. It has high wear-resistance, excellent toughness, and deep-hardening properties — everything you need for economical tool service.

Our booklet on air-hardening steels includes full data on Air-4. For your copy, write to Publications Department, Bethlehem Steel Company, Bethlehem, Pa. Ask for Booklet 548.

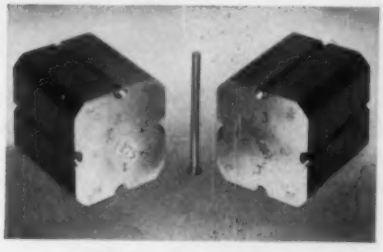
BETHLEHEM TOOL STEEL ENGINEER SAYS:

Lehigh H Is the Work-Horse Of the Cold-Extrusion Industry

Bethlehem's Lehigh H, a high-carbon, high-chromium (AISI type D-2) tool steel, is the most widely used tool steel in the cold-extrusion industry. And for good reasons. Lehigh H has an unusually good combination of properties: high compressive strength, deep hardenability, and high resistance to wear.

Lehigh H is used for a wide variety of cold-extrusion tools, such as punches and mandrels which are subject to compressive loads or abrasion. Whenever it is used for containers, bushings, or similar parts which are subjected mainly to tensile loads, it is supported by an external shrink ring.

Cold-extrusion tools of Lehigh H are usually made to a hardness of Rockwell C 58-60. Occasionally they are tempered back to C 55 to avoid breakage. Using a hardness above C 60 is not recommended, because such a hardness is obtained only at a sacrifice of proper tempering.

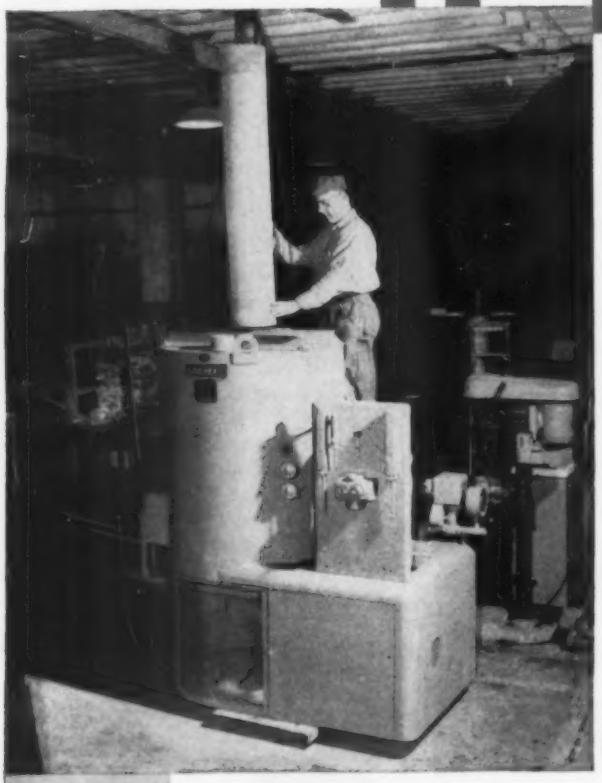


COLD-HEADING DIE STEEL SPEEDS HEADING OF SCREW BLANKS

These gripper dies are used by Southern Screw Company in forming blanks from steel wire. The dies, made of Bethlehem Cold-Heading Quality tool steel, produce about 150,000 blanks before redressing is required. Bethlehem Cold-Heading steel resists shock because it is carefully controlled for hardenability. It also has a carbon range selected to give good wear-resistance and high toughness.

DURALOY HOM

Covered by U.S. Patents.



Do your high alloy castings show a tendency to sag at 1800 to 2200°F? Is the operation important enough to use an alloy that stays firm at that temperature range?

Then HOM is your casting requirement. It would take an unusually heavy load to deform this metal. It was developed by Duraloy metallurgists to be usable over that high temperature range—another milestone in the ever broadening services available to industry through Duraloy.

Why not discuss your extra high temperature problem with our metallurgical staff? Send for Bulletin G-159.

ALLOY CASTING INSTITUTE ACI MEMBER

The DURALOY Company

OFFICE AND PLANT: Scottdale, Pa.

EASTERN OFFICE: 12 East 41st Street, New York 17, N. Y.
CHICAGO OFFICE: 332 South Michigan Avenue
DETROIT OFFICE: 23908 Woodward Avenue, Pleasant Ridge, Mich.

For more information, turn to Reader Service card, circle No. 366

Convair 990 main landing gear strut. The bracket is subjected to repeated loads of at least 36,000 lb during retracting; and, during flight, to continuous vibrations and varying G loads.

According to K. H. Pierce, vice president of Precision Castparts Corp., the part was formerly forged, and heat treated to a tensile strength of 200,000 psi to assure close dimensional control, then hogged out. As more than half of the original weight had to be removed from the forging, its hardness made the machining cost prohibitive.

Casting the bracket from stainless steel not only minimizes machining but, more important, improves its properties. The casting's uniform strength made it feasible to design the bracket to meet a wide variety of stress, load and vibration resistance requirements.

***Investment cast bracket** is complex in design. The 25-lb casting replaces a forged and machined part.*

Ultrasonic Transducer Is Coated Ceramic

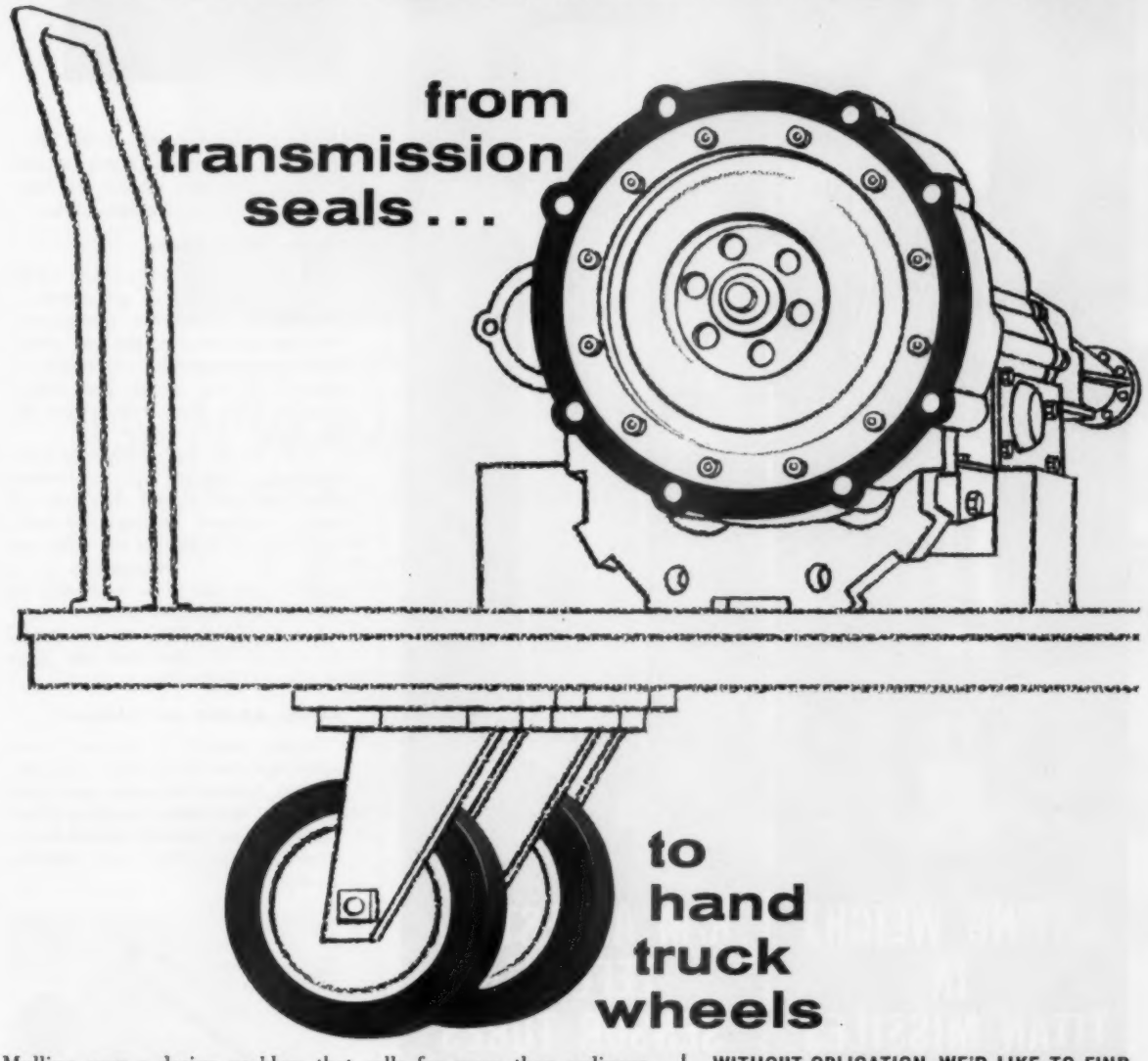
A new piezoelectric transducer that converts high frequency microwave signals into ultrasonic pulses and vice versa is expected to greatly increase the capacity of computer memory delay lines.

Gallium arsenide used

The new device consists of a plate of gallium arsenide semiconductor on which a thin (approx 0.00015-in.) metal film has been deposited. The film, in contact with the semiconductor, forms a "depletion layer," i.e., a thin region of controllable high resistance.

When an a.c. voltage is applied, most of the voltage drop occurs across the thin depletion layer. Con-

Your Firestone Technical Service Man shapes rubber compounds for everything . . .



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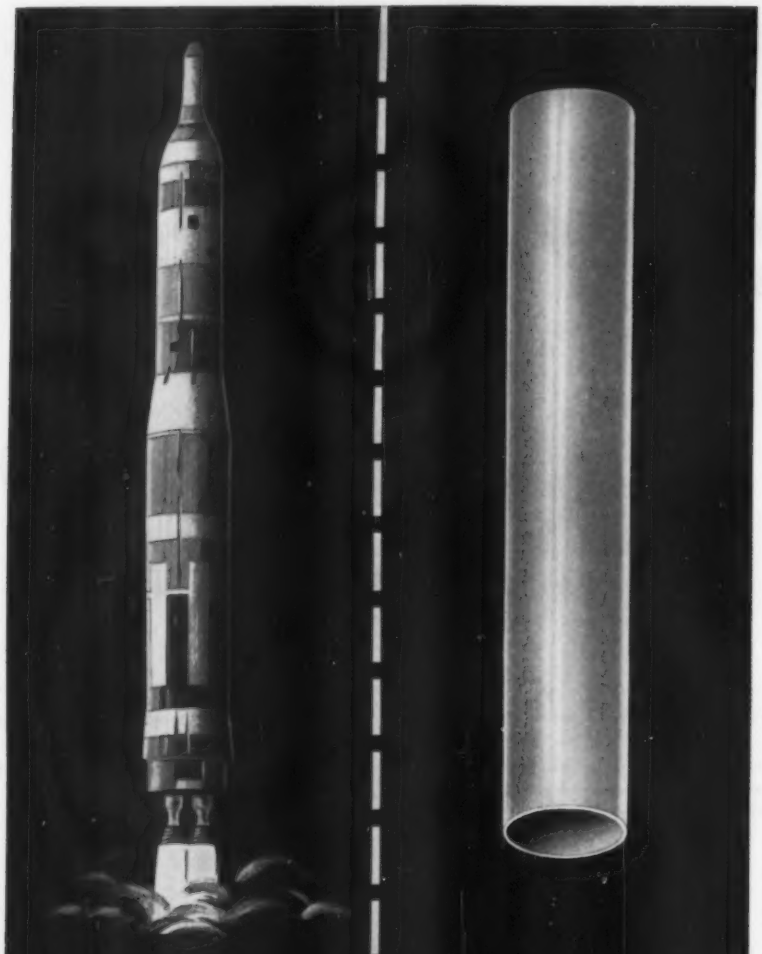

SAVING WEIGHT IN TITAN MISSILES:

R/M ASBESTOS-TEFLON* SENSOR TUBES

A new combination of high-heat materials, perfected by R/M, has reduced the weight of sensor tubes which help determine fuel load in Titan missiles.

These tape-wrapped tubes, 4 in. ID, 12 ft. long, weigh less than 0.67 lb. per foot—a substantial weight saving over any competitive tubes which meet the temperature, fuel compatibility, and strength/weight ratio requirements.

This is but one of the many applications in which R/M specialists are using their extensive "Teflon" experience to help missile and airframe manufacturers solve weight, compatibility, temperature and strength problems.

Write direct or call your nearest R/M district office listed below.

*Registered TM for Du Pont fluorocarbon resins

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SPECIALISTS IN ASBESTOS, RUBBER, ENGINEERED PLASTICS, SINTERED METAL

For more information, turn to Reader Service card, circle No. 357

sequently the strength of the electrical field is very high; strong alternating stresses vibrate the crystal and produce ultrasonic pulses.

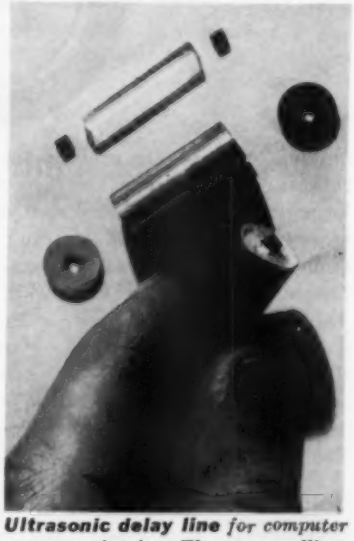
Longer delay times

Up to now, useful ultrasonic waves in solids could not be generated or detected at microwave frequencies. The high efficiency of the new transducer compensates for the solid's resistance to the waves and makes possible delay lines with longer delay times.

D. L. White, Bell Telephone Laboratories, described the new transducer at the recent Institute of Radio Engineers convention. According to White, a pair of the units can store far more information in a quartz delay line than is possible by other means. Another possible application is for studying the acoustical properties of materials at high ultrasonic frequencies.

Above 10,000 mc planned

Present models of the new transducer operate at less than 1000 mc, but Bell Laboratory scientists expect to extend the range to above 10,000 mc, where such devices should be far more efficient than any previous type.



***Ultrasonic delay line** for computer memory circuits. The two gallium arsenide transducers are bonded to each end of the 1-in. long quartz crystal delay line (top). The assembly is encased before installation.*

For high strength without excessive weight, the designer of this heavy truck chose Tenzaloy for the front engine supporting frame.

TENZALOY

Why TENZALOY is the most widely used high-strength aluminum casting alloy

Among high-strength, self-aging aluminum casting alloys, Tenzaloy has won greatest acceptance and widest use by designers because of its unique all-round combination of properties. Outstanding among these special qualities are:

- High yield and tensile strength, combined with adequate ductility
- Exceptional machinability
- Remarkable dimensional stability
- High impact, shock resistance

When Tenzaloy is specified, one big problem is eliminated: heat treatment. Without any artificial thermal treatment, Tenzaloy castings will precipitation-harden at room temperature to give properties normally obtainable only by the expensive solution treating, quenching, and artificial aging of the heat-treatable alloys.

Here are typical properties for Federated Tenzaloy:

Tensile strength	35,000 psi
Yield strength	25,000 psi
Elongation (in 2 in.)	4-5%
Brinell hardness No.	74
Impact strength (Charpy in ft.-lbs.):	
Notched	3
Un-notched	14
Electrical conductivity	35%

Tenzaloy also is corrosion resistant, has superior ductility, and is easily anodized, dyed and polished to brilliant decorative finishes. Castability is excellent in green sand, plaster, investment, shell, oil-bonded sand and precision molds of all kinds. No special techniques are required for handling Tenzaloy in the foundry. Since Tenzaloy has mechanical properties equivalent to such common heat-treated alloys as 195T6, 355T6, 356T6 and 319T6, it can be substituted in applications where any of these heat-treated alloys are presently used.

It is particularly suited to high-strength designs where load carrying capacity and impact strength are essential. For example: frames, brackets, levers, bases, housings, missile ground handling equipment, jet aircraft turntables, explosion-proof enclosures, heavy-duty wheel hubs and cable drums, to name a representative few.

Tenzaloy can widen your design possibilities, increase production efficiency, improve your products, reduce costs. Get complete facts on its physical and mechanical properties by writing for Bulletin No. 103 R5 to: Federated Metals Division, American Smelting and Refining Company, 120 Broadway, New York 5, N. Y.

FEDERATED METALS DIVISION **ASARCO**

American Smelting and Refining Company
120 Broadway, New York 5, N. Y.

For more information, turn to Reader Service card, circle No. 329

Complete ductwork system of new Humble Oil Building is . . .

GUARDED BY GALVANIZED STEEL

When this handsome Humble Oil office building in Houston, Texas, is finished in 1962, it will be the tallest building west of the Mississippi River. All 44 floors will be served by galvanized steel ductwork. That's 700 tons of skin-tight zinc-coated steel—a combination of tough durability and excellent corrosion protection with the broadest economy east *or* west of the Mississippi River. Galvanized steel's economy starts with fabrication, continues with erection and installation and is perpetuated in what little maintenance is required after that.

WEIRKOTE® IN PARTICULAR!—That's the choice of Mr. Harold W. Looney, owner of Looney's of Texas, Inc., sheet metal contractor, for all 700 tons of ductwork in this new building. To the inherent strength of steel—to its economy, versatility and advantageously low expansion/contraction rate—Weirkote adds flawless fabrication and long-lasting corrosion protection. Chip-free, crack-free, peel-free Weirkote is manufactured by two National Steel divisions, Weirton Steel and Midwest Steel. Write Weirton Steel Company, Weirton, West Virginia, for further details.

MIDWEST STEEL
Portage, Indiana

WEIRTON STEEL
Weirton, West Virginia

divisions of
NATIONAL STEEL CORPORATION

For more information, turn to Reader Service card, circle No. 346

(cont'd from p 15)

graph. Normal forging practice, in which the billet is heated, carried to the forging press and then forged, trimmed, and coined in separate operations, produces 300 links per hour.

With AmForge Div.'s automatic press, links are now produced at the rate of 720 per hr, and production of 1200 per hr is anticipated.

The track link is a good example of the type of part to consider for automatic forging. It meets the requirement for relative simplicity and is produced in such large numbers—the forging industry produces ten million track links each year for original equipment manufacturers—that the long production runs required (15,000 to 20,000 pieces, minimum) can easily be set up.

Automatic forging eliminates the need for tong hold space, leading to a second important advantage. Weight of the billet needed to produce the track link is reduced from 6 lb, 15 oz to 6 lb, 9 oz, a considerable saving in material when measured against ten million production units.

***Crawler tractor link** weighs 5.5 lb, is produced at the rate of 720 links per hr.*

Plastics Laminates for Electronic Parts

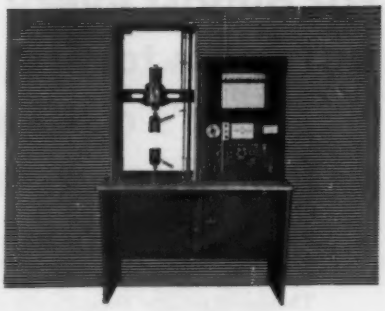
Four new plastics laminates have been introduced recently. Two of the laminates are epoxy-glass types, one is phenolic-paper, and the other is epoxy-paper.

1. Epoxy-glass laminates

An epoxy-glass laminate with a thickness tolerance of ±0.004 in. over 100% of the area on 1/16-in. thick sheets is available from Formica Corp., 4614 Spring Grove Ave., Cincinnati 32, Ohio. The laminate, called FF-91, is said to exceed the Class II tolerances of military specification MIL-P-13949B. The laminate is recommended as a plug-in connector material for electronic computers. It is supplied in 36 by 42-in. and 36 by 84-in. sheets with copper-clad or unclad surfaces.

Spaulding Fibre Co., 310 Wheeler St., Tonawanda, N. Y. has introduced a flame retardant epoxy-glass laminate that is said to be easier to fabricate than other flame retardant epoxy-glass grades. Called G-10-839, the laminate is supplied in 40 by 48-

***Epoxy-paper laminate** developed by Westinghouse's Micarta Div.*



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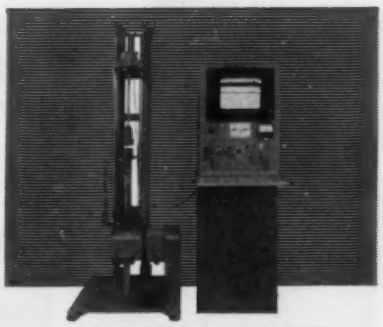
ELONGATION WIRE MATERIALS

VERSATILITY AND ECONOMY are key features of the Scott Model CRE Electronic Tester. You get ultra-high accuracy of inertialess electronic weighing . . . plus effortless, error-free, push-button testing of wire products *at amazingly low cost!* Stress-strain information "picturized" on strip chart. Ample magnification for detailed analyses of wire, insulation sheath, cable components. Interchangeable test capacities to 1000 lbs. For facts on Model CRE Tester, write **Scott Testers, Inc., 65 Blackstone St., Prov., R. I. Tel: DExter 1-5650 (Area Code 401).**

SCOTT TESTERS
THE SURE TEST . . . SCOTT!



TENSILE TEST CAPACITIES
TO 2000 LBS.

Scott Model J-5 Tester with ACCR-O-METER Electronic Weighing gives you a far greater range of quality evaluation for wire, insulation sheath, and cable components — and at modest cost! ACCR-O-METER strain gage weighing features *interchangeable* force dividers . . . provides for full scale test capacities of .5 to 2000 lbs. Push-button testing for both high and low elongation materials. Stress-strain information "picturized" on strip chart. Ample magnification for detailed test analyses. For top testing convenience, economy, versatility . . . get facts on ACCR-O-METER. **Scott Testers, Inc., 65 Blackstone St., Providence, R. I. Tel: DExter 1-5650 (Area Code 401).**

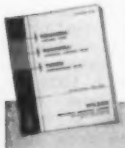
SCOTT TESTERS
THE SURE TEST . . . SCOTT!

For more information, circle No. 436

For almost every hardness testing requirement

There's a Wilson "Rockwell" instrument to do the job

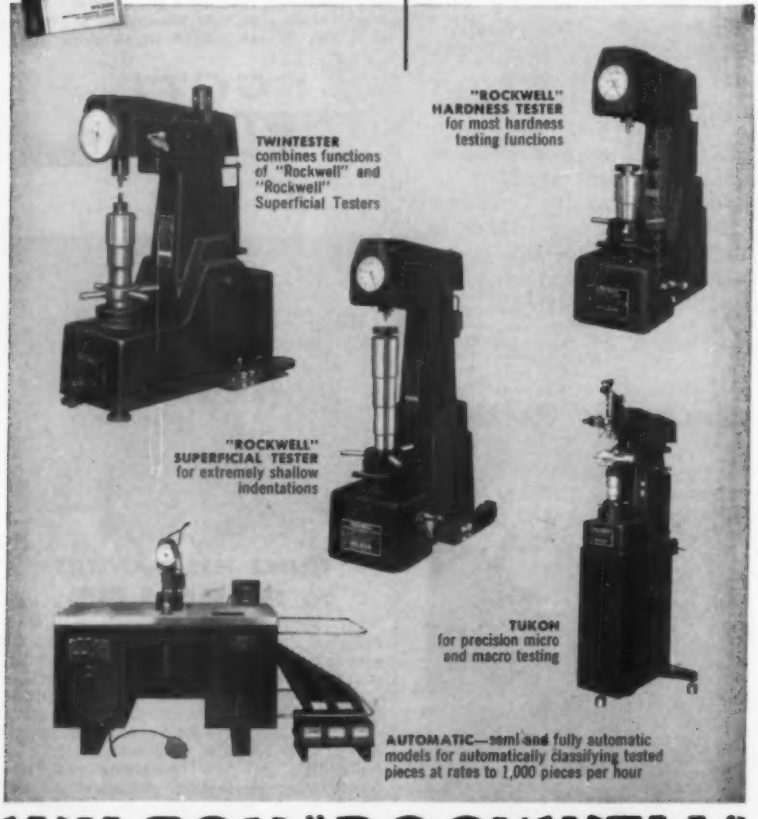
Wilson "Rockwell" Hardness Testers can help make your products better, stronger, longer lasting. They give reliable results on the production line, in laboratories, in tool rooms, and in inspection departments. They're as easy to use as a center punch, as durable as a machine tool, as sensitive and accurate as a precision balance. That's why Wilson "Rockwell" is recognized as the world's standard of hardness testing accuracy.



Write for Catalog RT-60. It gives complete details on the full line of Wilson hardness testing equipment.

Wilson "Brale" Diamond Penetrators give Perfect Readings

A perfect diamond penetrator is essential to accurate testing. Only flawless diamonds are used with Wilson "Brale" penetrators. Each diamond is cut to an exact shape. Microscopic inspection and a comparator check of each diamond—one by one—assure you of accurate hardness testing every time.


TWINTESTER
combines functions of "Rockwell" and "Rockwell" Superficial Testers
"ROCKWELL" HARDNESS TESTER
for most hardness testing functions
"ROCKWELL" SUPERFICIAL TESTER
for extremely shallow indentations
TUKON
for precision micro and macro testing
AUTOMATIC—semi and fully automatic models for automatically classifying tested pieces at rates to 1,000 pieces per hour

WILSON "ROCKWELL" HARDNESS TESTERS

Wilson Mechanical Instrument Division
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ACCO

For more information, turn to Reader Service card, circle No. 360

What's new IN MATERIALS

in. sheets with thicknesses ranging from 1/32 to 1 in. KEY NO. 610

2. Phenolic-paper laminate

A new phenolic resin has been developed by Richardson Co., 2724 Lake St., Melrose Park, Ill. for use in its new phenolic-paper laminate that is said to provide exceptional cold punching characteristics.

Called Insurok T-755, the new laminate has long shelf life, good solvent resistance and good reproducibility from shipment to shipment. It is expected to be used for printed circuits, terminal boards and other electrical and electronic parts.

The laminate is available unclad in 36 by 42 in. sheets and clad in 37 by 37 in. and 37 by 42 in. sheets.

KEY NO. 611

3. Epoxy-paper laminate

A new copper-clad epoxy-paper laminate is designed for printed circuit and other electronic applications requiring high strength and consistent electrical properties over a wide range of humidity levels. The laminate, designated Grade 65M24, is available from Westinghouse Electric Corp., Micarta Div., Hampton, S. C.

According to the producer, the new epoxy-paper laminate withstands a wider range of humidity levels than do the better grades of phenolic-paper laminates. The new grade costs less than NEMA G-10 and G-11 epoxy-glass laminates. It is supplied in sheets 36 by 36 in. and 36 by 72 in., in thicknesses ranging from 1/32 in. to 1/4 in. KEY NO. 612

Electrical Explosions Shape Exotic Metals

Low cost shaping of such hard-to-form metals as molybdenum, columbium, titanium, tungsten and stainless steel may be possible by using controlled electrical explosions.

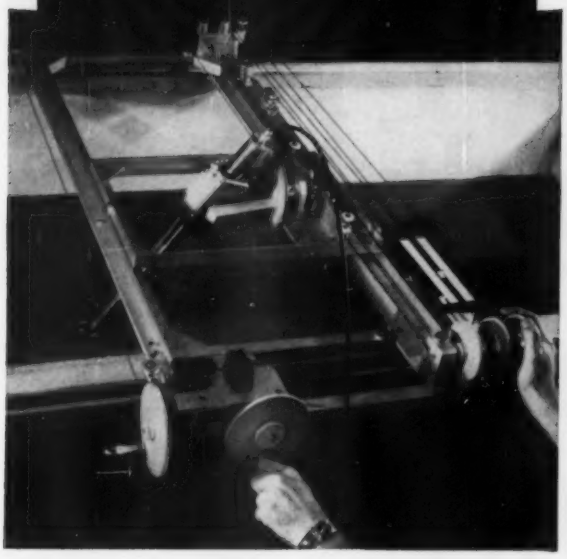
Under development at General Electric Co.'s General Engineering Laboratory, Schenectady, N. Y., the new process is described as "capacitor discharge electro-spark forming." No dynamite, TNT or other chemical explosives are used.

Shaping done under water

The explosions occur under water and are induced entirely through a

SCANNING BRIDGE

The Robot hands for ultrasonic flaw detection!



This "tailor-made" scanning bridge is used with the SONORAY® flaw detector. It holds the transducer in the required position and also permits its adjustment. The transducer may be raised or lowered, tilted in 2 planes or moved to any position in the tank.

Salient features:

- Ease of Operation (all controls are on one side and close to the operator)
- High-Accuracy Positioning
- Light in Weight, but sturdy
- Economy Priced

The scanning bridge is merely one of many outstanding examples of BRANSON ingenuity. This bridge was designed with the customer in mind! It was well-engineered at the lowest possible cost. The next time you have a problem, call BRANSON and see how fast BRANSON will find the best solution in the shortest possible time.

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17 Brown House Road, Stamford, Conn.

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Ask for 16-page brochure on sizes, groove dimensions, compounds and other helpful information.

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Diameters from 2" to 32". Capacities range from 1 quart to 100 gallons.

RELIABILITY is built right into Hackney-made components

Hackney forming methods produce strong, lightweight, seamless shells the cold drawn way. With smooth, clean surfaces, consistently uniform side walls and closely controlled tolerances, performance reliability becomes an integral part of every Hackney deep drawn shape or shell.

You will find plenty of design latitude in our methods because we make available to you a vast assortment of dies, mandrels and related tooling to match your ideas. Units can be made in sizes from 1 qt. to 100 gal. Diameters range from 2" to 32". Lengths may be from ½ to 5 times the diameter, or up to 110"...working pressures to 10,000 psi, depending on diameter.

Hackney experience and facilities can form your components in steel, magnesium, nickel, ultra-high-strength stainless steels, hot work tool steels, molybdenum or titanium. Let our engineers help you work out details and suggest ways to improve reliability...reduce cost. For complete information, write to the address below:

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What's new IN MATERIALS

Underwater explosion *induced by electricity is used to form titanium and other hard-to-form metals.*

buildup of electrical energy. The electrical blasts create high intensity shock waves which are directed against the metal pieces to be formed. Upon impact of the shock wave, the metal instantly takes the shape of the die into which it is blown. The die is evacuated to remove air pockets that could cause the piece to have surface irregularities.

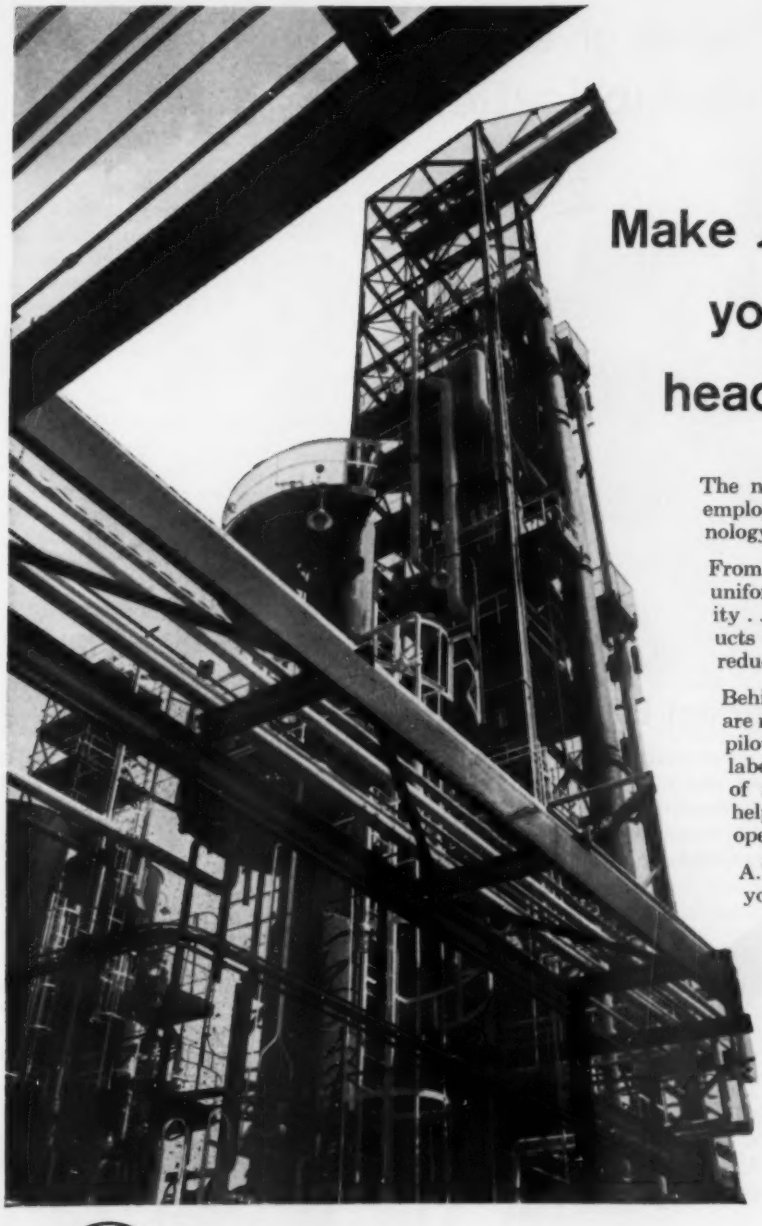
GE says the forming is done at room temperature and no preheating of metals is needed to make them ductile. The pieces take on the shape and surface texture of the die into which they are exploded and require minimum finish machining after they are removed.

The laboratory has formed pieces up to 10 in. in dia and 3/32 in. thick by the new process, but forming larger pieces is considered entirely feasible. (For information on other high energy rate forming processes, see M/DE, July '60, p 89.)

Neoprene-Base Paint for Outdoor Uses

A new neoprene-asphalt type coating is designed for use on tanks, pipes, bridges, box car roofs, ships and other products exposed to outdoor weathering.

Called Perfecote No. 701, the coating is available from Esbec Corp.,



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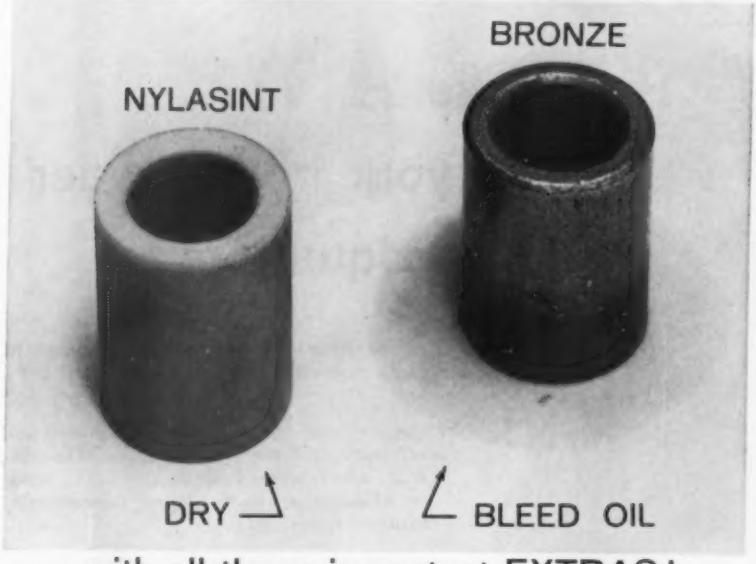

with all these important EXTRAS!

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- Lower hygroscopic and thermal expansion
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- Longer life, trouble free service

Unlike oil-impregnated, sintered bronze which bleeds readily on paper (see above), NYLASINT sintered nylon parts hold up to twice as much oil, are permanently lubricated to reduce friction, increase wear resistance and eliminate contact corrosion.

Inorganic additives also give resilient NYLASINT parts outstanding dimensional stability and high load capacity . . . important for such diverse fields as missile components and steel office furniture.

With NYLASINT you get all the prime advantages of nylon plus extra performance no other material offers in applications such as bearings, bushings, rollers and gears.

For complete technical data on NYLASINT, call or write for new NYLASINT Bulletin BR-1111.

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What's new IN MATERIALS

P. O. Box 929, Stamford, Conn.

Tests show the coating has excellent resistance to salt spray, water, sunlight and weathering. It has poor resistance to oils and solvents. The coating can be used at temperatures up to 200 F without sagging or flowing.

The producer says that primers are not usually required before applying the coating to metals, wood and concrete. The coating can be applied to damp surfaces. It dries in 1 hr at room temperature to a hard, firm surface. **KEY NO. 613**

New Casting Method Cuts Piece Cost 50%

An innovation in the production of nonferrous investment castings is said to reduce piece cost by as much as 50% because much higher production rates are possible than with conventional investment casting techniques.

The method, called Planar, has been developed by Atlantic Casting & Engineering Corp., 810 Bloomfield Ave., Clifton, N. J.

The developer says close, rapid cut-off is possible with the new process, since the entire tree of castings is located in one plane (see accompanying photo). Surface finishes and tolerances produced by the

***Tree** of manganese-bronze castings is made from a single mold in Atlantic's new investment casting process.*

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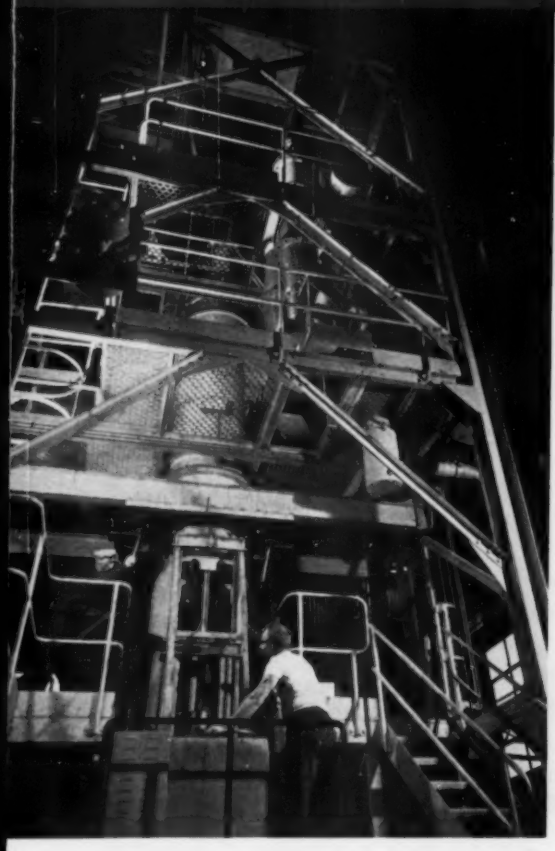
CONSUMABLE VACUUM MELTED

"the highest quality money can buy"



On critical applications when only the best will do—specify CVM (Consumable Vacuum Melted) steels and alloys from Vanadium-Alloys Steel Company. Our CVM label is your assurance of unsurpassed quality and purity.

To begin, our steels are melted under stringent tool steel practice in order to insure electrodes of the highest quality and purity. Our versatile vacuum melting furnace, with closely regulated power input, enables us to melt 9½", 12", 16", 20", and 24" ingots at continuous vacuum pressures below one-half of a micron for maximum degassification.

A half-century of experience melting a wide variety of alloys has taught us how to realize the highest structural quality from each composition. Pleased customers regularly report higher physicals and better metallurgical structures with our melts as compared with the same grades produced in other furnaces.

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*4330+V	*A-286	317 Stainless
*4335+V	Inco 901	410 Stainless
*4340	V-57	436 Stainless
*4350	*52100	M-1 High Speed Steel
300 M	*51100	*M-2 High Speed Steel
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For more information, circle No. 426

ACID
Havar (hā′ vär) n. A non-magnetic wear- and corrosion-resistant alloy which has high fatigue resistance. It can be heat treated to tensile strengths in excess of 350,000 psi.

no other metal has the combination of properties found in new HAVAR

Designers looking for a new and versatile metal are finding practical answers in the unique properties of Havar. This unusual material is a corrosion-resistant, non-magnetic alloy with high fatigue resistance and high tensile strength. It possesses exceptionally high resistance to permanent deformation, thus permitting a more constant delivery of torque over extended periods.

New Havar is being used for critical springs and process control diaphragms, torque control drive bands, electronic computers and—because of its ductility and corrosion resistance—for orthodontic wire.

Havar was developed by the Metals and Electronics Division of Hamilton Watch Company. It is presently available in bars, wire, strip and in foil in thicknesses down to 0.0001" at tolerances closer than you can imagine.

Write today for complete data on engineering properties and processing instructions. Ask for the Havar Technical Data Sheet—or for a sample of Havar. Dept. DE-6.

HAMILTON

WATCH COMPANY / Metals and Electronics Division

Lancaster, Pennsylvania

For more information, turn to Reader Service card, circle No. 404

process are comparable to those of conventional investment castings.

How process works

1. Individual wax or plastic disposable patterns which incorporate gating are plugged into permanent, withdrawable runner patterns.

2. The assembly is then invested and the permanent runner pattern withdrawn, leaving the gate extremity of the disposable pattern exposed to heat as the mold moves through an oven. Wax evacuation, burn-out and mold drying then take place in a single, fast cycle.

The company says the dry, one-piece molds are ready for pouring in less than one-fourth the time required with multi-cycle batch production methods used in conventional investment casting techniques.

Special mold material

According to the developer, a special mold material (nature not disclosed) eliminates the need for using metal flasks to reinforce and protect molds throughout the casting process. The mold can be exposed to high heat for wax evacuation with no danger of breakage. Thus, break-out time in the new process is much faster than with conventional investment casting techniques using metal flasks. **KEY NO. 614**

Flexible Polyethylene Competes with Vinyls

Development of a new flexible polyethylene, a copolymer of ethylene and ethyl acrylate, has been announced by Dow Chemical Co., Midland, Mich. It sells for 32½¢ per lb in truckload lots for natural.

The resin is somewhat similar to a new elastomeric polyethylene discussed in the May issue of this magazine (p 14).

Designated Zetafin, the resin is expected to compete with flexible vinyls in a number of applications. Reason: it has properties similar to those of flexible vinyls but is easier to process. The polyethylene contains no plasticizers, precluding the possibility of migration or volatilization problems, and eliminating the need for compounding. Another ad-

HANDY ALLOY DATA SHEET

HANDY & HARMAN ENGINEERING DEPARTMENT
82 FULTON STREET, NEW YORK 38, N.Y.

TEC and TEC-Z

...How to choose between a soft solder and a brazing alloy

Handy & Harman provides *two* alloys that fit between "something stronger than the average soft solder but not as strong as a silver-brazing alloy." They are named TEC and TEC-Z and their flow points are intermediate between soft solders and silver-brazing alloys. Joints made by these alloys are strong in straight tension or shear. For instance, butt joints of cold-worked copper can be made having a tensile strength of about 25,000 psi. This is approximately 10,000 psi. more than can be obtained with tin-lead soft solders. TEC joints retain their strength at elevated temperatures much better than the tin-lead soft solders. As shown in the table below, the strength of the solder itself at 425° F is about the same as a 50% tin–50% lead solder at room temperature in short-time tensile tests.

Applications—One example is a thermostatic bellows where the operating temperature is too high for soft solders (tin-lead), yet requires a joining medium which will not anneal the bellows. Another use is gun parts which require joint strength at higher than soft-solder operating temperatures *plus* corrosion resistance to solutions used in cleaning and blackening. Also for lamp bulb bases operating at approximately 350°-500° F. Automotive applications and heat exchangers. TEC conforms to Government Specifications Mil-S-19234 (Nord); both TEC and TEC-Z are available in sheet, wire, powder, and preforms to specifications.

NOMINAL COMPOSITIONS

	TEC	TEC-Z
Silver	5% plus or minus 0.5%	5% plus or minus 0.5%
Zinc		16.6% plus or minus 0.5%
Cadmium	95% plus or minus 0.5%	78.4% plus or minus 0.5%

PHYSICAL PROPERTIES

	TEC	TEC-Z
Color	White	White
Melting Point	640° F	480° F
Flow Point	740° F	600° F
Density (Troy oz/cu in.)	4.60	4.53
Electrical Conductivity (Cu = 100)	22.0%	20.6%
Electrical Resistivity (Microhm-cm)	7.9	8.4

STRENGTH COMPARISON TEC vs. Pb-SN

	TENSILE STRENGTH LBS/SQ IN. TEC	TENSILE STRENGTH LBS/SQ IN. Pb-SN
ROOM	16,400	2,500
300° F	4,400	650
425° F	2,600	Melts
500° F	1,700	

The information and data on this page are available in our Handy Alloy Data Sheet. Ask for "TEC." Handy & Harman, 850 Third Avenue, New York 22, N. Y.

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it's new
it seals
it saves

it's DELRIN*

Another RB&W development from Delrin plastic, this new threaded plug replaces more expensive metal plugs in many hydraulic and compressor applications.

It not only saves on cost and weight, but also does a better job. Fluid pressure forces mating threads together, creates a still tighter seal, locks threads in place.

Metal-like mechanical properties of Delrin provide excellent strength, dimensional stability, rigidity. Count also on resistance to corrosion and solvents.

Available in ⅛, ¼, ⅜, ½" pipe sizes. Send for samples.

Ask about other parts you would like custom-molded from Delrin, or other thermoplastics, in production quantities.

Write Russell, Burdsall & Ward Bolt and Nut Company, Port Chester, New York.

*DuPont trademark

RB&W
116th year

For more information, circle No. 339

What's new IN MATERIALS

vantage is that temperature control during processing is not as critical as with flexible vinyls.

Three grades available

No. 30 is designed for extrusion and blow molding applications. It has a melt index of 2.5.

No. 35 is a film-grade resin designed for such applications as place mats, draperies, table cloths and possibly inflatable toys. It contains anti-block additives to minimize blocking tendencies in thin-gage film. Melt index: 2.5.

No. 70 is an injection molding grade that is said to offer a high degree of flexibility and surface gloss. Melt index: 18.0.

Noted briefly in our May issue.

KEY NO. 615

Beryllia Heat Sinks for Semiconductors

Beryllium oxide's unique ability to resist the flow of electricity but not the flow of heat is being used to advantage in new dielectric heat sinks now available off-the-shelf from National Beryllia Corp., First & Haskell Ave., Haskell, N. J. The heat sinks were previously available only

Large steel die forging—This 10,000-lb main axle beam for the B-70 intercontinental jet bomber is said to be the largest closed die forging ever made of H-11 chromium hot work tool steel. The forging was made on a 125,000 MKG (meter-kilogram) counterblow forging hammer by Ladish Co., Cudahy, Wis.

KEY NO. 616

Need Thinner & Wider Precision STAINLESS and SPECIAL ALLOYS in THIN STRIP and FOIL?

Rodney Specializes in Close-Tolerance Thinness... Unique Service Described in Free Catalog!

Rodney concentrates its entire efforts, research and production, toward furnishing super thin, extra wide, precision rolled, metal strip and foil in all tempers and finishes. With the entire capacity of plant and personnel devoted exclusively to this specific area, Rodney can offer the added "know-how", manufacturing experience, quality control, and application knowledge your operation may require.

Rodney produces stainless steel strip . . . all alloys . . . in widths from ⅛" to 24" . . . at gauges from .012" to .0003". Rodney also rolls high temperature alloys and other special alloys on a production basis. Aluminum alloys, carbon steel strip and specialty custom rolling are also handled.

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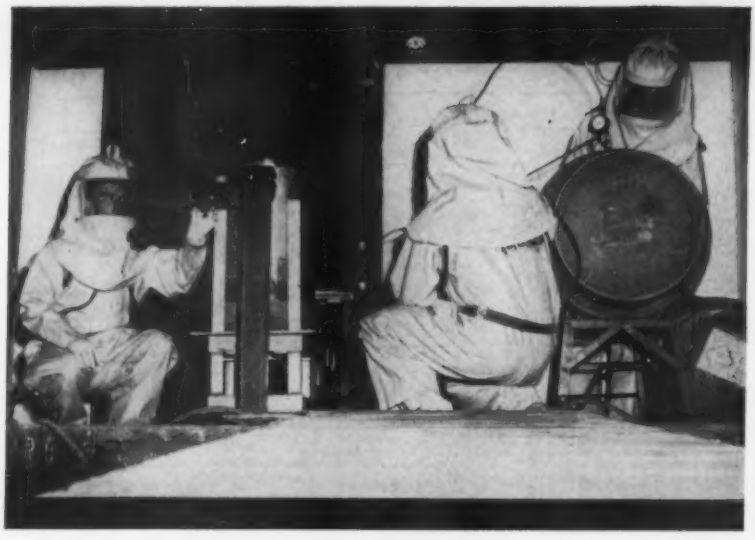

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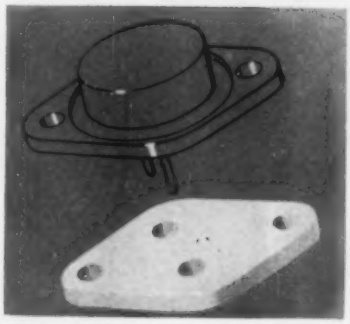
What's new IN MATERIALS



Beryllia heat sinks *keep semiconductor temperatures down.*

in small made-to-order quantities.

The heat sinks, called Berlox, are said to maintain semiconductor temperatures at least 50% lower for a given power level than those permitted by conventional dielectric heat sinks.

The heat sinks have extremely low dielectric loss (<0.0008) over the entire frequency range at which semiconductors are used. They also have good resistance to shock, vibration and moisture, are free of outgassing, and have infinite shelf life.

Berlox heat sinks are available to match JEDEC (Joint Electronic Device Engineering Council) outlines TO3, 5, 8, 9, 11, 12, 16, 18, 33, 38 and 39. Standard thickness is 1/16 in.

KEY NO. 617

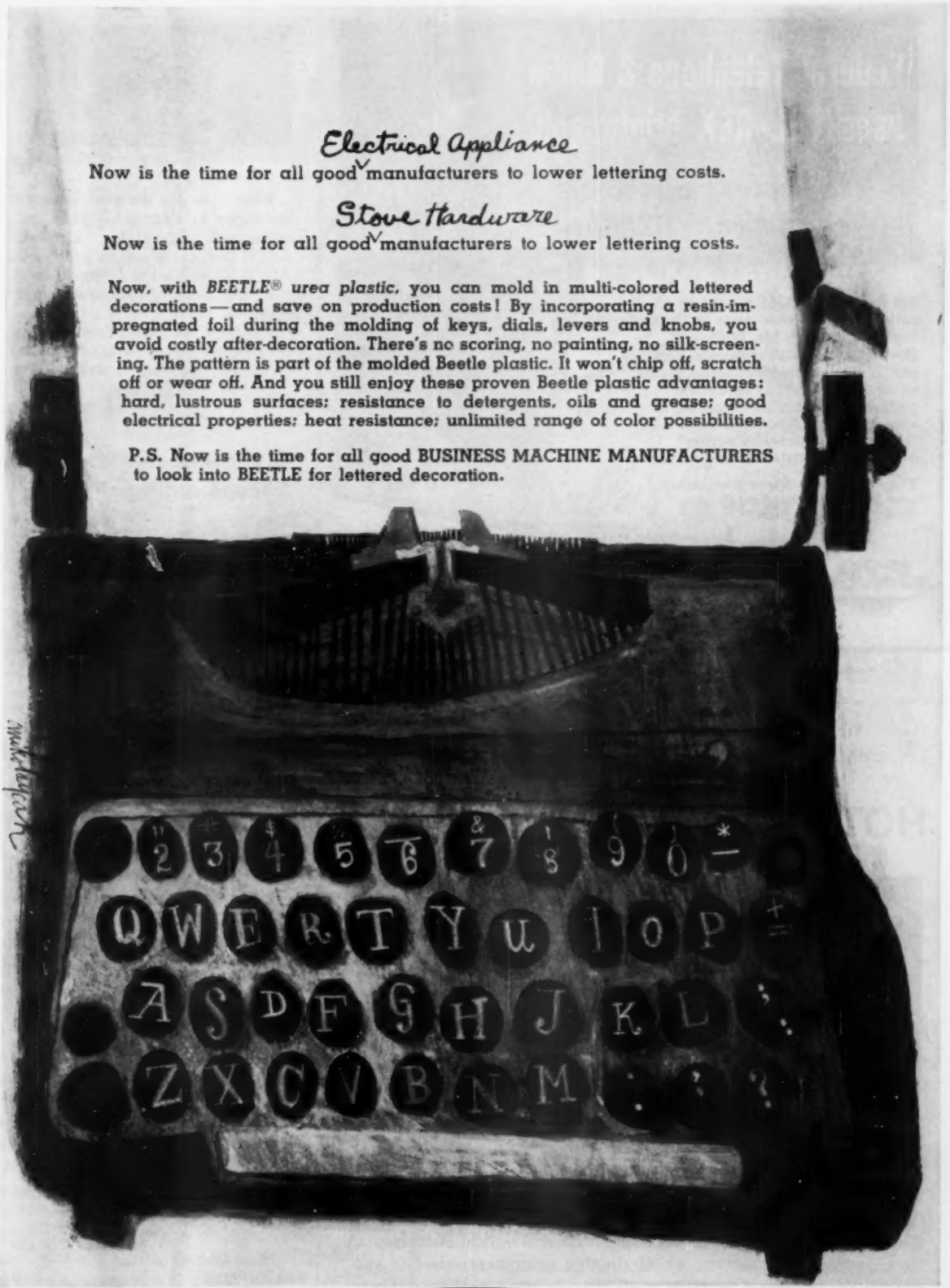
Vinyl Surfacing Mat Is Abrasion Resistant

A new vinyl surfacing material is designed as a decorative and protective surface for appliances, vending machines, folding doors and business machines, and as a flooring for station wagons and boats. Big advantage of the material is its excellent abrasion resistance and good flexibility.

Called Autocord, the material is available in a variety of colors from Armstrong Cork Co., Industrial Div., Lancaster, Pa. It can be bonded to metallic and nonmetallic materials with various types of adhesives.

The material consists of a filled vinyl compound joined to a resin-saturated asbestos fiber backing. The wearing surface has a molded-in embossed design.

(continued on p 178)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Now is the time for all good manufacturers to lower lettering costs.
Now, with *BEETLE® urea plastic*, you can mold in multi-colored lettered decorations—and save on production costs! By incorporating a resin-impregnated foil during the molding of keys, dials, levers and knobs, you avoid costly after-decoration. There's no scoring, no painting, no silk-screening. The pattern is part of the molded Beetle plastic. It won't chip off, scratch off or wear off. And you still enjoy these proven Beetle plastic advantages: hard, lustrous surfaces; resistance to detergents, oils and grease; good electrical properties; heat resistance; unlimited range of color possibilities.
P.S. Now is the time for all good BUSINESS MACHINE MANUFACTURERS to look into BEETLE for lettered decoration.

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Federal Telephone & Radio uses SEL-REX bright gold

to improve electronic component reliability

Sel-Rex Bright Gold is used on a variety of electronic parts at Federal because, to quote Mr. William F. Boyle, Chief Metallurgist, the deposits are "...fine grained and dense, giving exact duplication of the surface plated... (it) eliminates galling in sliding electrical contacts" and has "effected a tremendous saving" over previous materials and methods.

The Federal Telephone story, other case histories and technical data FREE on request.

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Hot type or cold type, whichever serves your purposes, Liberty Mirror can supply front-surface or back-surface mirrors with Hi-Efficiency dichroic coatings applied by vacuum-deposition. They are highly durable and easily cleaned with non-abrasive cleaners. The coatings themselves will withstand ambient temperatures of minus 60°F. and plus 600°F.

Other vacuum-deposited coatings of aluminum, chrome or gold are used to make first-surface mirrors, neutral filters, transparent mirrors, high-efficiency beam splitters and laminated mirrors.

Applied to glass, optical parts, metal, epoxy or plastic, the coatings are used in such varied products as scientific and optical instruments, toys, cameras, pin setters, wheel-aligning equipment, aircraft and missiles. If you have a potential application or new use, Liberty Mirror engineers will help you solve your problems. Technical data sheets available on all coatings. Write L-O-F, Liberty Mirror Division, 2361 Libbey-Owens-Ford Building, Toledo 1, Ohio.

For more information, turn to Reader Service card, circle No. 371

Tests show the material has good resistance to hydrogen sulfide, 3% ammonium hydroxide, kerosene, ASTM fuel A, 1% sodium hydroxide, ASTM No. 3 oil, 1% detergent solution, 0.7% laundry soap solution and vegetable oil.

The new surfacing material is supplied as die-cut parts or in rolls.

KEY NO. 618

Clear Silicone for Encapsulating, Potting

A new transparent silicone resin for encapsulating, potting, filling and embedding electronic parts has been introduced by Dow Corning Corp., Midland, Mich. The resin cures in place after blending with a curing agent to form a flexible, transparent solid with good moisture resistance.

Properties of the resin, called Sylgard 182, are given in the accompanying table.

Dow Corning supplies another transparent silicone for electronic applications. Unlike Sylgard 182, it forms a gel on curing and is self-healing. Called Dielectric Gel, the silicone fluid was introduced in 1959 (M/DE, June '59, p 138). The gel cannot be used as an encapsulant

PROPERTIES OF SYLGARD 182

PROPERTIES BEFORE CURE	
Specific Gravity (77 F)	1.05
Viscosity (77 F), cs	5000
Shelf Life (77 F), months	>6
Pot Life (77 F), hr	>6
PROPERTIES AFTER CURE*	
Hardness (Shore)	A40
Water Absorption (7 days), %	0.10
Brittle Point, F	−90
Dielectric Strength, v/mil	1000
Dielectric Constant (60 cps)	
77 F	2.88
212 F	2.76
300 F	2.61
390 F	2.46
Dissipation Factor (60 cps)	
77 F	0.0010
212 F	0.0010
300 F	0.0015
390 F	0.0050
Volume Resistivity, ohm-cm	
77 F	5×10^{13}
212 F	7×10^{13}
300 F	3×10^{12}
390 F	8×10^{15}

*Cured 4 hr at 150 F.

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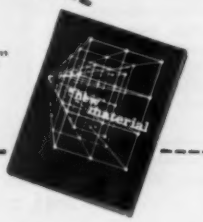

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by P. WILLIAM LEE
Head, Porcelain Research Department, The Dentists' Supply Company

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SPECIAL ATTENTION IS GIVEN
to new and recent developments in this important field. Many new ceramic materials have been developed which have unique engineering properties for specialized fields of use. The author discusses a number of these materials as well as the new fabricating techniques.

THIS BOOK WILL PROVE HELPFUL
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CONTENTS:
Introduction—Principal Raw Materials Used in Classic Ceramics—Brief Introduction to Ceramic Chemistry—White Wares—Artware—Ceramics for Electrical and Electronic Uses—Dental Porcelain—Structural Clay Products—Refractories—Glass—Porcelain Enamel—Ceramic Abrasives—Cermets—New Developments in Ceramics—Appendix: Ceramic Raw Materials.

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What's new IN MATERIALS

since it is not self-supporting.

Components and circuits encapsulated in Sylgard 182 resin are clearly visible. The cured resin can be cut away with a sharp knife so that defective components can be repaired or replaced. New resin bonds to the original material.

Sylgard 182 cures in 15 min at 300 F, 4 hr at 150 F and 3 days at 75 F. **KEY NO. 619**

***Silicone encapsulant** can be twisted or rolled to conform with circuit placement requirements.*

Galvanized Sheet Has Improved Paintability

A new, spangle-free galvanized sheet has been introduced. The hot-dipped sheet is said to combine improved paintability and weldability with the good corrosion resistance of sheet having a 1.25 oz per sq ft zinc coating (ASTM A-93).

Current spangle-free zinc-coated sheets include those with thin electrogalvanized and hot dipped light commercial zinc coatings.

The new galvanized sheet, called Zincgrip A, Paintgrip, joins another galvanized sheet introduced recently by Armco Steel Corp., Middletown, Ohio. The earlier grade, called Zincgrip DC, has a hot dipped zinc coating on one surface and a smooth, spangle-free finish on the other (M/DE, Mar '61, p 182).

Sheet can be drawn, formed

Armco says its new galvanized sheet can be drawn, formed and

Here's How Haveg Solved the Problem... with HAVELEX®

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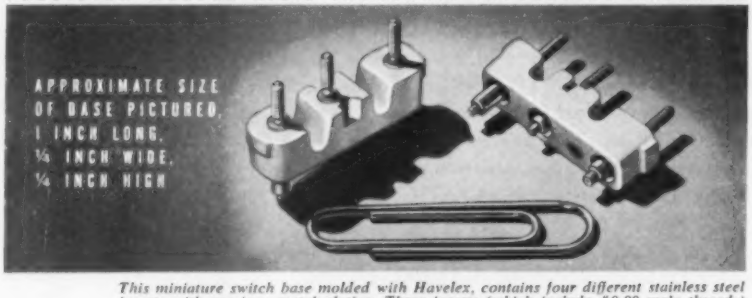

This miniature switch base molded with Havelex, contains four different stainless steel inserts with precious metal plating. Three inserts (which include #0-80 male threads) go all the way through the mold and provide precision mountings on both sides for assembly. The #0-80 female threaded insert is designed to protrude from one face and is approached by a molded counterbore from the other. Mold is designed to accommodate alternate terminal inserts when unthreaded models are required.

Haveg engineers recommended Havelex for this particular molding because of its combination of properties. Completely inorganic, with metal inserts integrally molded in place. Precision tolerances with faithful reproduction from part to part. Heat resistance for continuous operation in excess of 700°F.

Haveg engineers will be happy to work with you on your particular project—to help you "Keep ahead with Haveg." *Remember*—Havelex offers all of these unique features: **Dimensional Stability • 1000°F. Continuous Temperature Resistance • Dielectric Strength • Mechanical Strength • Low Loss, Low Power Factor • Arc Resistance • No Moisture Absorption • Integrally Molded Metal Inserts • Hermetically Sealed Inserts.**

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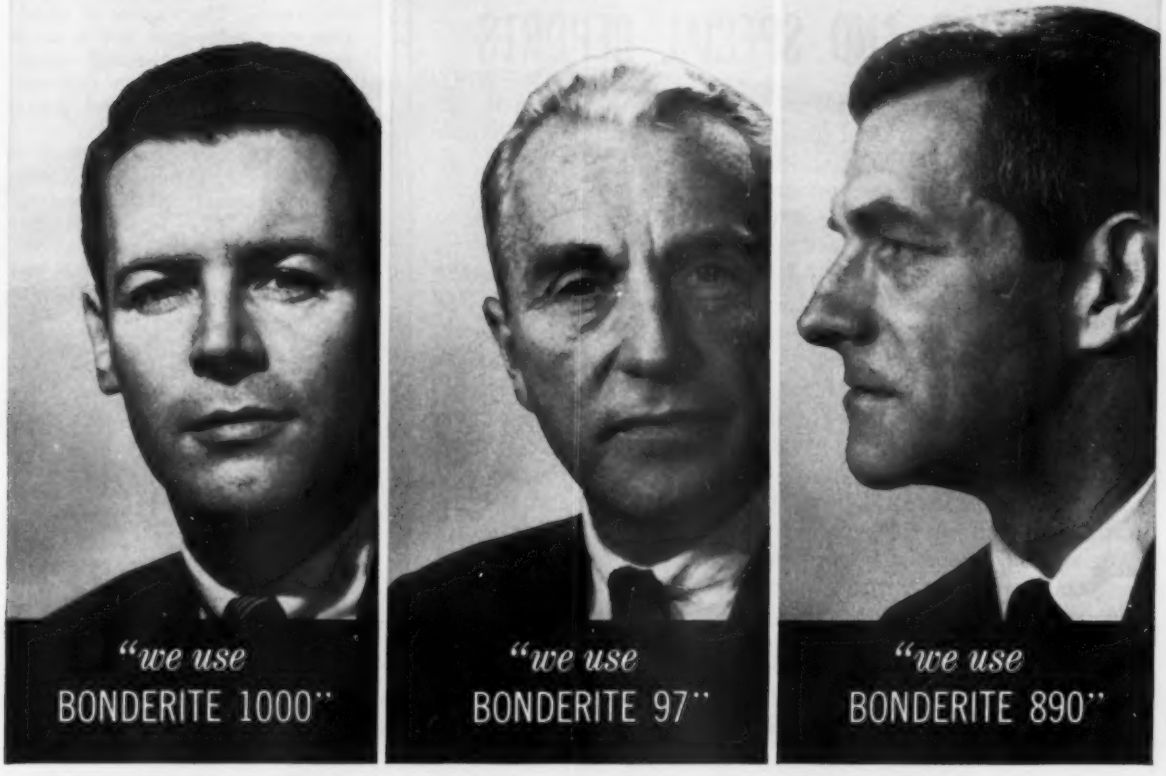
Three manufacturers with similar products–



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lock seamed to the limit of the base metal without flaking or peeling of the coating. The number of resistance spot welds that can be made on the sheet before tips need redressing is more than double that possible on regular galvanized sheets, according to the producer.

The new material is expected to be used in automotive, appliance, farm equipment and architectural applications.

It is supplied as coils and cut lengths in gages 16 through 24 and in widths up to 48 in. **KEY NO. 620**

***Panels** of new galvanized sheet (top), one painted and the other unpainted, showed no signs of rusting after three years' outdoor exposure. Painted and unpainted panels of cold rolled steel (bottom) showed definite signs of rusting after being exposed for the same length of time.*

Rubber Liners Protect Metal Against Abrasion

Two new materials—a fabric-backed urethane rubber liner and a natural rubber liner—are designed to protect the surfaces of chutes, mills, dust collectors, and shot and sand blast machinery against abrasion.

1. Urethane rubber liner

The fabric-backed urethane rubber liner, called PO-663, is available in standard stock sheet sizes ranging from 12 by 20 in. to 90 by 40 in., and in thicknesses from 1/8 to 1/4 in. from Armstrong Cork Co., Industrial Div.,

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PB-172

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Lancaster, Pa. The liner is designed especially for handling grain, ore slurries, coal, coke, rock, sand, gravel, glass and other abrasive materials. The urethane rubber liner can be easily installed by cementing or bolting.

KEY NO. 621

***Steel chute** (left) lined with Armstrong's new fabric-backed urethane rubber shows only slight surface abrasion, whereas unlined chute (right) is worn through after being used the same length of time as the lined chute in a grain loading operation.*

2. Natural rubber liner

The natural rubber liner, designated Jade Green Armabond, is available in gages from 1/8 to 1/2 in. and in 48 in. widths from Goodyear Tire & Rubber Co., Akron 16, Ohio. According to the producer, the liner provides complete protection to metal and nonmetallic surfaces against the impinging abrasion and chemical action of most inorganic salts, alkalis and acids. The natural rubber liner can be bonded to a wide variety of surfaces, including metals, fabrics and other rubber compounds.

KEY NO. 622

New Organic Coating Resists Acids, Mortar

A new organic coating is said to protect aluminum and other nonferrous metals against the harmful effects of acids, alkalis and outdoor exposure. Called Perma-Cote 61, the coating is available from S. C. Johnson & Son, Inc., Service Products Div., Racine, Wis.

A big advantage of the coating is that it passes a 30-day laboratory test for acid and mortar resistance as specified by the Aluminum Window Mfrs. Assn. The company says that Perma-Cote 61 appears to be the only single-layer coating that passes this test.

The coating (composition not disclosed) is colorless and nonyellowing. It forms a tough, glossy film that will not discolor when exposed to ultraviolet rays. The coating dries tack-free in 2 to 3 min at room temperature.

KEY NO. 623

Other News . . .

Metals

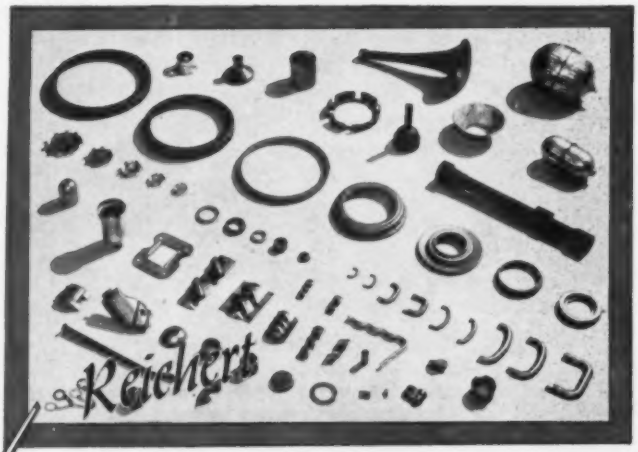
▸ Floor plates rolled from high strength steel have been introduced by Jones & Laughlin Steel Corp., 3 Gateway Center, Pittsburgh 30. The plates are available in thicknesses ranging from 3/16 to 1/2 in., lengths to 360 in. and widths to 48 in.

KEY NO. 624

▸ Investment cast parts made of high temperature alloys are being turned out by a new process in which vacuum melted alloys are vacuum investment cast. The technique was developed by Haynes Stellite Co., Div. of Union Carbide Corp., New York 17.

KEY NO. 625

Deep Drawn,
Light and Medium
COPPER
BRASS
ALUMINUM
MONEL
STAINLESS
HIGH CARBON
ALLOY STEELS



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Nickel alloy steels safeguard the working accuracy of this Barber-Colman lathe

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THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street New York 5, N. Y.

INCO NICKEL

NICKEL MAKES STEEL PERFORM BETTER LONGER

▸ Precision-ground flats and squares made of AISI type D-2 high carbon–high chromium die steel are now available from Vanadium-Alloys Steel Co., Latrobe, Pa. The steel is ground to a 30-μin. finish.

KEY NO. 626

Plastics & Rubber

▸ A fluorocarbon-blown polyurethane insulating and soundproofing material has been introduced by Foam Products Mfg. Ltd., 823 Gilman St., Berkeley, Calif. Called Flo-Foam, the material can be applied by spraying or pouring in place. It has a thermal conductivity of 0.14 Btu/hr/sq ft/°F/in. at 75 F.

KEY NO. 627

▸ An easy-to-apply reinforced fluorocarbon slip and anti-stick agent is available from Dixon Corp., Bristol, R. I. in aerosol spray cans. The material, called Rulon, is said to provide a fast, simple way to obtain low friction, slick surfaces for wood, metals, leather and plastics.

KEY NO. 628

▸ Mylar polyester tubes are now available from Resinite Corp., 6984 N. Central Park Ave., Chicago 45, in i.d.'s ranging from 0.040 to 8 in. Wall thicknesses range from 0.001 to 0.050 in.

KEY NO. 629

▸ A polyvinyl chloride resin for calendered, injection molded and extruded products has been introduced by Goodyear Tire & Rubber Co., Chemical Div., Akron 16, Ohio. The resin, designated Pliovic S-75, is said to have excellent handling characteristics and good heat stability.

KEY NO. 630

Other nonmetallics

▸ A gold fleck overlay paper for decorative applications has been introduced by Fitchburg Paper Co., 642 River St., Fitchburg, Mass. The paper is made with all the gold flecks on one side of the overlay to prevent tarnishing, discoloring and loss of flecks in finished products.

KEY NO. 631

▸ An ultra-clean lubricating grease for use on miniature instrument bearings has been introduced by Miniature Precision Bearings, Inc., Keene, N. H. It is called Minapure.

KEY NO. 632

▸ Subminiature parts made of high alumina ceramics are now available in production lot quantities from Diamonite Products Mfg. Co., Shreve, Ohio. Tubes and cylinders are made in sizes as small as 0.050 in. o.d. by 0.030 in. i.d. by 0.045 in. long.

KEY NO. 633

Finishes

▸ Kenvert No. 26 is the name of a new bright dip that produces a clear, bright finish on cadmium in a single dip. It is available from Conversion Chemical Corp., 98 E. Main St., Rockville, Conn.

KEY NO. 634

▸ A new machine that automatically loads, ultrasonically cleans and degreases, dries and unloads tote box loads of metal parts has been announced by Autosonics, Inc., 4217 Chestnut St., Philadelphia 4. The machine, called AutoSonex, is particularly useful for delicate assemblies and parts that cannot tolerate impingement or tumbling.

KEY NO. 635

▸ A fluorescent gloss enamel is offered by Advance Process Supply Co., 2315 W. Huron St., Chicago 12. The enamel, called Lumi-Glo, is said to be excellent for decal processing.

KEY NO. 636

Joining, fastening

▸ A self-adhering adhesive for acetate, polystyrene, vinyl and polyethylene blister packaging has been announced by Adhesive Products Corp., 1660 Boone Ave., New York 60. The water-base adhesive is called Blis-Stix.

KEY NO. 637

▸ A tamper-proof fastener for use on electrical boxes and other products has been introduced by Reliance Div., Eaton Mfg. Co., Massillon, Ohio. The fastener, called Torqtite, requires a special tool for driving and loosening.

KEY NO. 638

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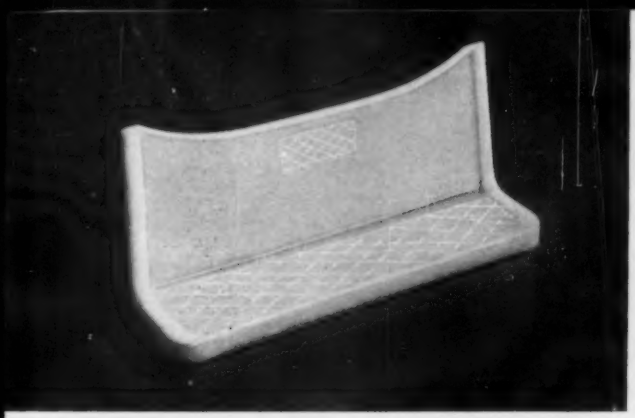
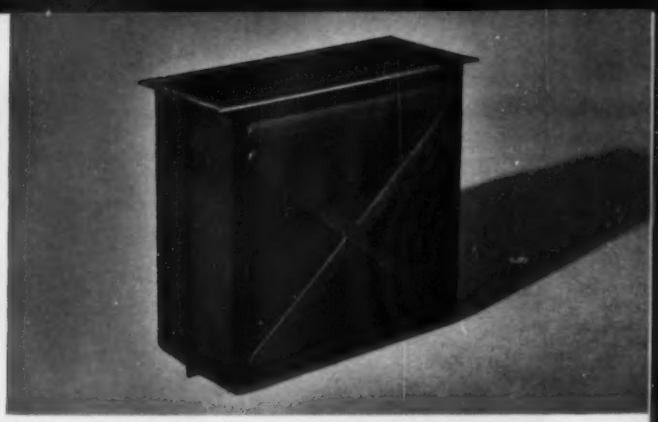


FOOT REST—Attractively molded high chair foot rest by Joseph P. Miller, Inc., has permanent color and finish . . . won't crack or splinter . . . hard, easy-to-clean surface.



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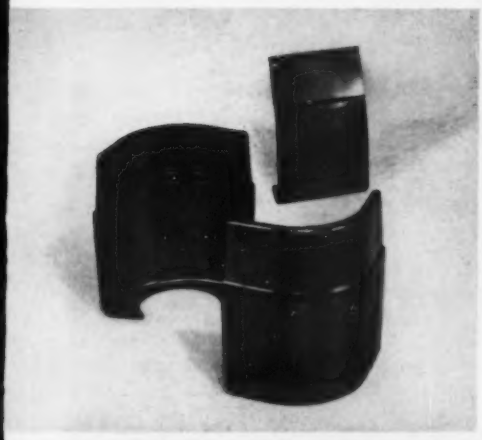

BILLIARD TABLE PARTS—Functionally styled with integral color and texture for Superior Industries Corp., N.Y.C. Because of MARLEX, these parts won't chip, dent, warp or crack.

MARLEX* furniture components improve product quality

To improve products and keep costs down, more and more furniture manufacturers rely on components molded or formed from MARLEX high density plastics. These high-quality plastics are lightweight, tough, and virtually indestructible . . . resistant to denting, cracking, acids, alkalies, greases, fungi, corrosion . . . and possess a wide usable temperature range (—180°F to 250°F). Components of MARLEX can be molded, thermoformed, extruded, welded, machined, printed upon . . . never need refinishing.

*MARLEX is a trademark for Phillips family of olefin polymers.

HIGH CHAIR TRAY—This tray from Napco Plastics is sturdy and rugged. Smooth, hard MARLEX surface is non-absorbent, non-allergenic, easy to keep clean.

SMALL COMPONENTS—Self-lubricating drawer slides, non-marring furniture glides, and tough dowel pins—examples of low-cost, better performing MARLEX furniture parts.

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Bartlesville, Oklahoma

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PHILLIPS 66 MARLEX PLASTICS

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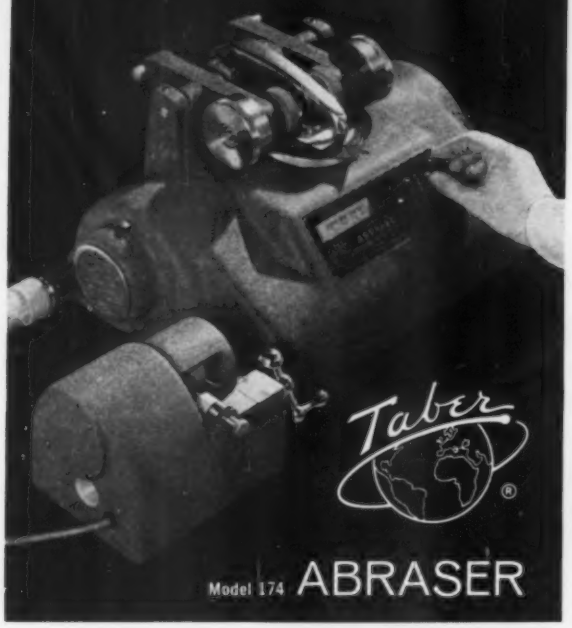
measures wear-life of numerous materials ... hot, cold, wet or dry



Has hundreds of applications: plastics, paints, lacquers, electroplating, textiles, metals, leather, rubber, linoleum, etc. Easy-to-operate, the Taber Abraser simulates actual wear conditions. A rotary rub action is applied by dual abrading wheels . . . one rubbing the specimen from the center out and the other from the outside toward the center. With the specimen rotating full circle, abrasion resistance is revealed at all angles relative to the material's weave or grain.

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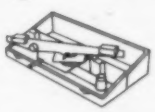

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MAIL bulletin(s) describing
☐ Abraser ☐ Stiffness Tester ☐ Shear/Scratch Tester

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Company
Street
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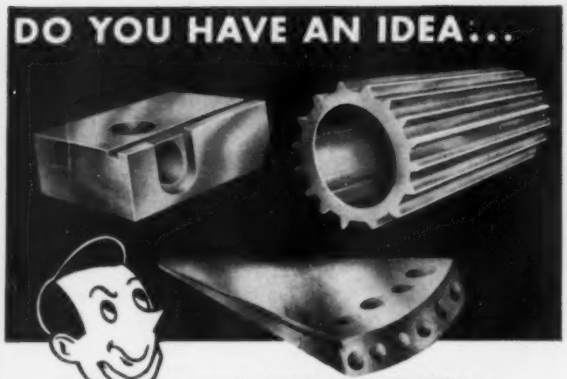

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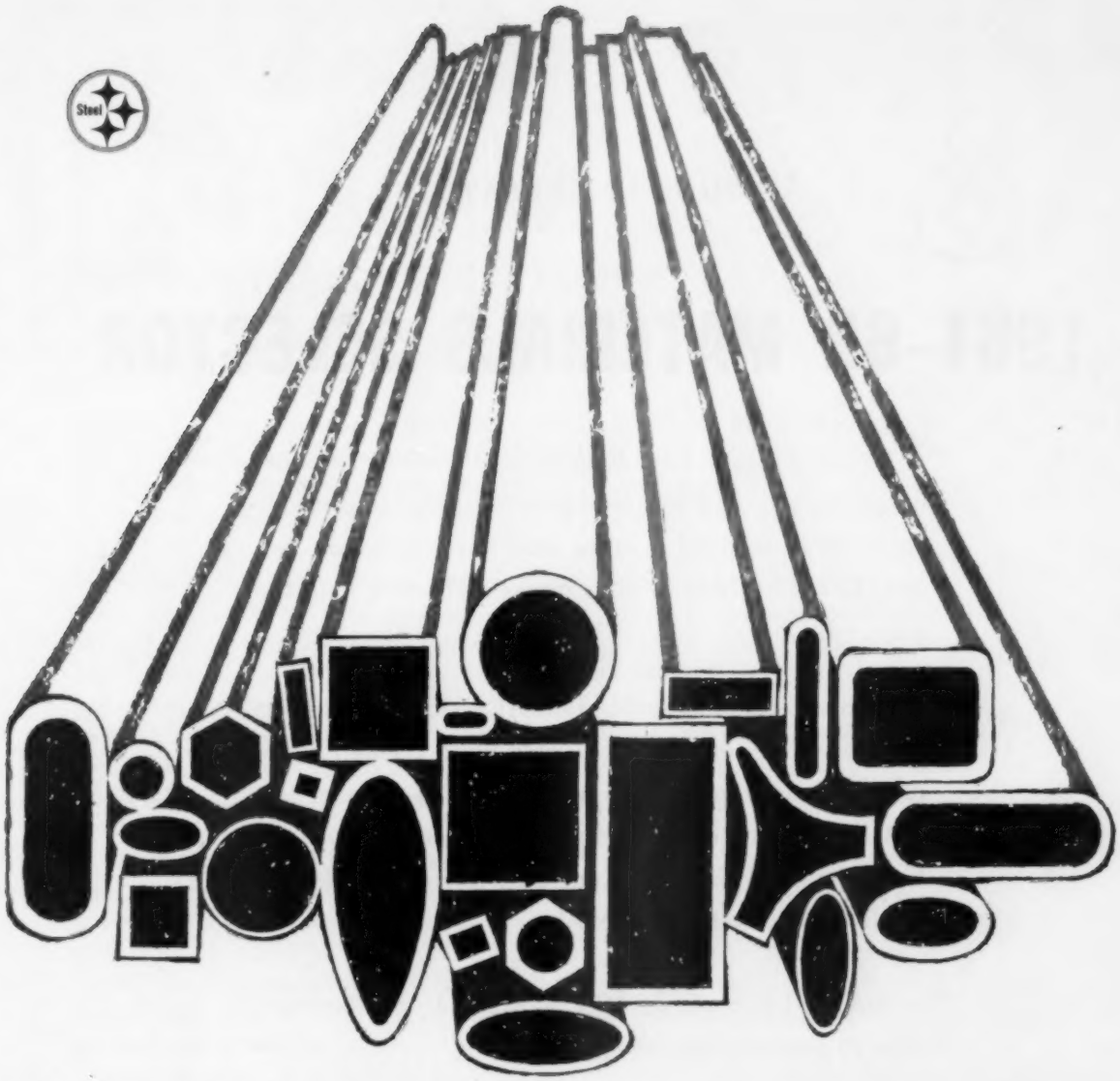

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The quality producers at left are prepared to help you design with tubing in all weldable grades of carbon, stainless steel and other alloys. You can get useful information from any of them or you can write for your free Booklet 8591, Dept. MD-3, Welded Steel Tube Institute, Inc., Hanna Building, Cleveland 15, Ohio. It will pay in uniformity, safety, and savings in weight.

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KNOW YOUR ALLOY STEELS . . .

This is one of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many who may find it useful to review fundamentals from time to time.

Steel

for Strength
. . . Economy
. . . Versatility

Determining the Proper Depth of Case in Alloy Steels

In one of the recent articles in this series we discussed the carburizing of alloy steels, pointing out that the purpose of carburizing is to provide a hard, abrasion-resistant outer shell or "case." Such a discussion naturally gives rise to the question, What factors influence the choice of case? Should it be shallow? Medium? Deep or extra-deep?

While it is not always wise to formulate hard-and-fast rules, the following may be used as a general yardstick:

Shallow cases (less than 0.02 in.). Suitable where wear-resistance alone is the chief requirement, and where good surface condition after heat-treating is advantageous. Not suitable if high stresses are apt to be encountered in service.

Medium cases (0.02 to 0.04 in.). For high wear-resistance. Will stand up under substantial service loads and stresses. The thickness is sufficient to permit certain finishing operations, such as light grinding.

Medium-to-deep cases (0.04 to 0.06 in.). For high wear-resistance. A case in this depth range is essential where continuing friction is involved, especially friction of an abrasive or semi-abrasive nature. It is also a good precautionary measure where application of the finished part may sometimes involve crushing action.

Extra-deep cases (more than 0.06 in.). Cases of this depth can be obtained by extending the furnace time in pack carburizing. Highly wear-resistant, extra-deep cases also withstand shock and impact. A large camshaft of an internal-combustion engine is a good example of a part requiring the extra-deep case. This is especially true of the cam lobes themselves.

If you need advice concerning case-hardened parts, let us arrange for one of our metallurgists to assist you. Bethlehem engineers are always on call, and you can depend on their recommendations. And you can depend on Bethlehem, too, when you need alloy steels; for Bethlehem makes the full range of AISI standard grades, as well as special-analysis steels and all carbon grades.

This series of alloy steel advertisements is now available as a compact booklet, "Quick Facts about Alloy Steels." If you would like a free copy, please address your request to Publications Department, Bethlehem Steel Company, Bethlehem, Pa.

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA. *Export Sales:* Bethlehem Steel Export Corporation

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TO BOND SANDWICH CORE USE METLBOND 406

today's most advanced metal-fastening adhesive system

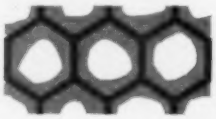
METLBOND 406 is a large-area, one-component, low-pressure, dry, epoxy-based adhesive system. METLBOND 406 will bond similar or dissimilar metals faster, cheaper, better. No core or skin primer is required.

METLBOND 406 IS EASY TO USE. It can be cut, placed in position, and cured with low pressure, at moderate temperatures. Since it is a non-supported system, there is no fabric carrier. Therefore, during cure, it flows . . . goes where you want it! For most structural metal-joining operations, use METLBOND 406—the "educated" adhesive. It can measurably cut your fabrication costs.

IMPORTANT CHARACTERISTICS OF METLBOND 406

Effective operating temp. range . . −430F to +200F
Room temp. shear strength . . . . . 5500 psi
Room temp. peel strength (in.-lbs. per 3-in. width) 125
A dual-purpose adhesive system which can be used to bond metal-to-metal, or core-to-skin with equal effectiveness.

FILLETING ACTION OF METLBOND 406



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Setting Trends in Refrigeration Since 1938

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AND COMPRESSIBILITY OF

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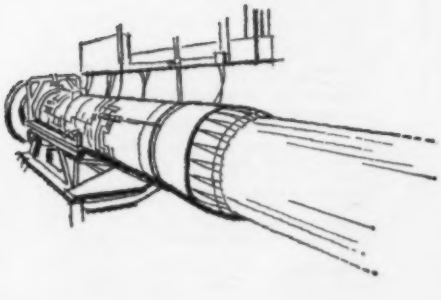
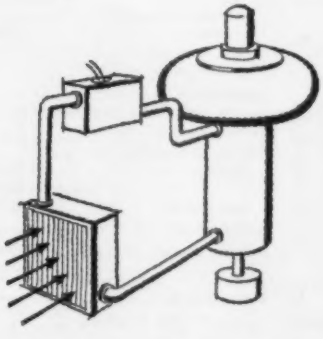


Extreme temperature lubricants For high temperature lube applications, General Electric silicone lubricating fluid Versilube F-50 gives unmatched thermal and oxidative stability over the temperature range of —100°F to 600°F. Its lubricity is unequalled at temperatures as high as 600°F, and comparable to other fluids in the moderate ranges. Excellent hydrolytic stability. Not corrosive to common metals.



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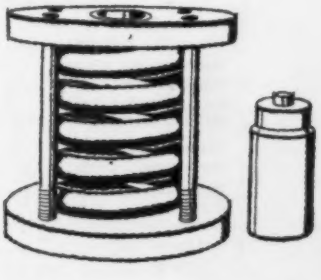

Compressible fluids This liquid spring, which utilizes the compressibility of G-E silicone fluids, can do the same work as a conventional spring five times as heavy. All G-E silicone fluids have relatively constant viscosity over wide temperature ranges, and high-temperature stability. Viscosities range from 5 to 100,000 centistokes at 25°C. Ideal for hydraulic fluids, fluid drives, dashpots, and dampers.

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The benefits of General Electric silicone fluids find uses in hundreds of products, from jet engines to suntan lotions. To learn more about these versatile, problem-solving fluids, write: General Electric Company, Silicone Products Dept., Section B647, Waterford, New York.

GENERAL ELECTRIC

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***Get more information* on advertised products by circling the key numbers found on the advertisements *(not the page numbers below)* on the free postal card, pp 43-44.**

Abrasives 76
Adhesives 90, 102, 194
Aluminum and its alloys 22, 163
Brazing alloys 173
Carbides, cemented 70
Carbon, graphite 72, 156, 190
Casting alloys 2, 160, 163
Castings
  Centrifugal 54, 92
  Die 2, 89, 188
  Investment 73
Ceramics 154
Ceramoplastics 24
Coatings 175
  Chemical conversion .. 26-27, 63, 158, 181
  Dispersion 53
  Metallized 190
  Organic 52, 81
  Vacuum deposited 178
Cold treating cabinets 194
Contact materials, electrical 67
Copper and its alloys
  inside front cover, 85
Diaphragms 21
Expanded metals 50-51
Extrusions
  Metallic 188
  Nonmetallic 194
Fabrics, coated 21
Fasteners, mechanical 60, 74-75, 174
Forgings 95
Indium and its alloys 23
Insulating materials 24, 180
Iron, malleable 64-65
Laminates
  Metal-plastic 36
  Plastics 20, 88, 94, 104, 190
Lead and its alloys 183
Lubricating materials 155
Metal powder presses 91
Metal powders 3, 98, 169
Mica, glass-bonded 24
Molybdenum and its alloys 25
Nickel and its alloys 4, 78, 185
Nonmagnetic alloys 172
Perforated parts 190
Plastics
  ABS 86-87
  Acrylic 35
  Epoxies 79, 83
Fluorocarbons 157
Phenolics 79
Polyamides (nylon) 28, 61-62, 93, 170, 186
Polycarbonate 71
Polyethylenes 8, 42, 55, 187
Polypropylene ..... 39, 42, 55, inside back cover
Polystyrenes 42, 55, 56-57
Reinforced 84
Urea 177
Vinyls 86-87
Plastics moldings 82, 89, 186
Plating processes, solutions 178
Precious metals 67
Precoated and preplated metals
  50-51, 58-59, 77, 164
Pressure vessels 168
Quartz, fused 67
Refractory materials 30-31, 80
Rings, nonmetallic "O" 167
Rubber
  Silicone 16
  Synthetic 6, 37, 161
  Urethane 32, 86-87
Sealing alloys, ceramic-metal 154
Seals 186
Silicones 149-150, 195
Slip ring assemblies 67
Solders 23, 173
Springs 184
Steel
  Heat and corrosion resistant 4, 33, 74-75, 78, 185, 189
  Low alloy 193
  Specialty 68-69, 179
  Tool and die 159
Strip, precision rolled 14, 174
Temperature indicators 96
Testing equipment .. 152, 165, 166, 167, 188
Testing service 176
Tubing and pipe
  Metallic ..... 74-75, 92, 191, outside back cover
  Nonmetallic 20, 162, 190
Tungsten and its alloys 70
Vacuum melted alloys 66, 74-75, 171
Wire 25, 29, 40-41
X-ray film 101
Zirconium and its alloys 18

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Ace Plastic Co. 194
Paul Smallen Advertising

Alan Wood Steel Co. 169
Aitkin-Kynett Co., Inc.

Allied Chemical Corp., Plastics Div. 28
McCann-Erickson Advertising

***Allied Research Products, Inc.** 63
Emery Advertising Corp.

Amchem Products, Inc. 26, 27
Al Paul Lefton Co., Inc.

***American Cast Iron Pipe Co., Acipco Steel Products Div.** 92
Robert Luckie & Co., Inc.

***American Cyanamid Co., Plastics and Resins Div.** 177
Erwin Wasey, Ruthrauff & Ryan, Inc.

American Nickeloid Co. 77
Kenneth B. Butler & Associates

***American Smelting and Refining Co., Federated Metals Div.** 163
Ward William & Co.

Anaconda American Brass Co. ..... 2nd Cover
Kenyon & Eckhardt, Inc.

Armco Steel Corp. 58, 59
Marsteller, Rickard, Gebhardt and Reed, Inc.

***AviSun Corp.** ..... 3rd Cover
Arndt, Preston, Chapin, Lamb & Keen, Inc.

Bethlehem Steel Co. 60, 95, 159, 193
Hazard Advertising Co., Inc.

***Branson Instruments, Inc., Ultrasonic Test Div.** 167
Faulkner Advertising Inc.

Bridgeport Fabrics, Inc. 186
S. R. Leon Co., Inc.

Carborundum Co., Refractories Div. 30, 31
G. M. Basford Co.

Carpenter Steel Co. 66
Beaumont, Heller & Sperling, Inc.

***Celanese Polymer Co., Div. of Celanese Corporation of America** 8
Ellington & Co., Inc.

***Chicago Molded Products Corp.** 82
Marsteller, Rickard, Gebhardt and Reed, Inc.

***Ciba Products Corp.** 83
Briggs & Varley, Inc.

Cleveland Container Co. 20
Nesbitt Service Co.

Continental-Diamond Fibre Corp., Sub. of Budd Co. 104
Aitkin-Kynett Co., Inc.

Coors Porcelain Co. 154
Galen E. Broyles Co., Inc.

Dallin Corp. 188
Thoma & Gill

Dow Corning Corp. 16, 149, 150
Church and Guisewite Advertising, Inc.

***du Pont de Nemours, E. I., & Co., Inc., Elastomer Chemicals Dept.** 32
N. W. Ayer & Son, Inc.

du Pont de Nemours, E. I. & Co., Inc., Film Dept. 157
Batten, Barton, Durstine & Osborn, Inc.

du Pont de Nemours, E. I. & Co., Inc., Polychemicals Dept. 61, 62
Batten, Barton, Durstine & Osborn, Inc.

***Duraloy Co.** 160
Sanger-Funnell, Inc.

***Durez Plastics Div., Hooker Chemical Corp.** 79
Rumrill Co., Inc.

Eastman Kodak Co., X-ray Sales Div. 101
J. Walter Thompson Co.

Electrofilm, Inc. 155
Danken Associates

***Engelhard Industries, Inc.** 67
Stuart Sande Advertising

Enjay Chemical Co., Div. of Humble Oil & Refining Co. 39
McCann-Erickson Advertising

Firestone Rubber & Latex Products Co. 161
Campbell-Ewald Co.

***General American Transportation Corp., Konigen Div.** 34
Edward H. Weiss and Co.

General Electric Co., Chemical Materials Dept. 71
G. M. Basford Co.

General Electric Co., Laminated Products Dept. 88
Jay H. Maish Co.

General Electric Co., Silicone Products Dept. 195
Ross Roy-Brooke, Smith, French & Dorrance, Inc.

***General Extrusions, Inc.** 188
R. J. McCallister Co.

Goodrich, B. F., Chemical Co., Div. of B. F. Goodrich Co. 6, 86, 87
Griswold-Eshleman Co.

Goodrich-Gulf Chemicals, Inc. 37
Griswold-Eshleman Co.

Goodyear Tire & Rubber Co., Chemical Div. 97
Kudner Agency, Inc.

***Goshen Rubber Co., Inc.** 167
Chamberlin-Junk Advertising Inc.

Grace, W. R., & Co., Polymer Chemicals Div. 42
de Garmo, Inc.

Great Lakes Steel Corp., Div. of National Steel Corp. 68, 69
Campbell-Ewald Co.

Gries Reproducer Corp. 89
Harold Marshall Advertising Co., Inc.

Hamilton Watch Co., Metals and Electronics Div. 172
Beaumont, Heller & Sperling, Inc.

***Handy & Harman** 173
Hazard Advertising Co., Inc.

***Haveg Industries Inc., Taunton Div.** 180
Wildrick & Miller, Inc.

***Hoeganaes Sponge Iron Corp.** 98
Norman A. Strong, Advertising

***Indium Corporation of America** 23
Farquhar and Co., Inc.

International Nickel Co., Inc. 4, 78, 185
McCann-Marshall Co., Inc.

***Jones & Laughlin Steel Corp., Stainless and Strip Div.** 14
Palmer, T. N., & Co., Inc.

***Kennametal Inc.** 70
Ketchum, MacLeod & Grove, Inc.

LaSalle Steel Co. 179
Fensholt Advertising Agency

***Libbey•Owens•Ford Glass Co., Liberty Mirror Div.** 178
Fuller & Smith & Ross Inc.

Linde Co., Div. of Union Carbide Corp. ... 76
J. M. Mathes, Inc.

Lockheed Aircraft Corp., Missiles and Space Div. 38
Hal Stebbins Inc.

***Maas & Waldstein Co.** 175
Lewis Advertising Agency

***Malleable Castings Council** 64, 65
Carr Liggett Advertising, Inc.

Materials in Design Engineering 182

Materials Selector 192

McLouth Steel Corp. 33
Denman & Baker, Inc.

***Metal & Thermit Corp.** 81
Marsteller, Rickard, Gebhardt and Reed, Inc.

Metallized Carbon Co. 190
Alexander Portegal

Midland Industrial Finishes Co. 52
Western Advertising Agency

Minnesota Mining and Manufacturing Co., Adhesives, Coatings and Sealers Liv. ... 102
MacManus, John & Adams, Inc.

Minnesota Mining and Manufacturing Co., Chemical Div. 53
MacManus, John & Adams, Inc.

Misco Precision Casting Co., Div. of Howe Sound Co. 73
Wallace-Blakeslee, Inc.

Monsanto Chemical Co., Plastics Div. 56, 57
Needham, Louis and Brorby, Inc.

***Mycalex Corp. of America** 24
Kelly, Nason, Inc.

Narmco Materials Div., Telecomputing Corp. 194
McNaughton-Laub, Inc.

***National Carbon Co., Div. of Union Carbide Corp.** 72
J. M. Mathes, Inc.

***National-Standard Co.** 40, 41
Marsteller, Rickard, Gebhardt and Reed, Inc.

New Jersey Zinc Co. 2, 3

***Norton Co., Refractories Div.** 80
Chirurg & Cairns, Inc.

Nylon Molded Products Corp. 186
PDA Advertising Agency

***Oakite Products, Inc.** 158
Marsteller, Rickard, Gebhardt and Reed, Inc.

Olin Mathieson Chemical Corp., Metals Div. 22
Doyle • Dane • Bernbach • Inc.

Parker Rust Proof Co. 181
Fred M. Randall Co.

***Perforating Industries, Inc.** 190
Raymond/Nicholas Advertising

Phillips Chemical Co., Plastics Sales Div. .. 187
Lambert & Feasley, Inc.

Polymer Corp., Halox Corp. Sub. 170
Beaumont, Heller & Sperling, Inc.

Pressed Steel Tank Co. 168
Buchen Advertising, Inc.

***Raybestos-Manhattan Inc., Adhesives Dept.** 90
Gray & Rogers

***Raybestos-Manhattan, Inc., Plastic Products Div.** 162
Gray & Rogers

***Reeves Brothers, Inc., Vulcan Div.** 21
Ketchum, MacLeod & Grove, Inc.

***Reichert Float & Mfg. Co.** 184
Wendt Advertising Agency

Reinhold Publishing Corp. 180

***Republic Steel Corp.** 74, 75
Meldrum & Fewsmith, Inc.

Revco, Inc. 194
Howard Swink Advertising Agency, Inc.

Riehle Testing Machines Div., American Machine and Metals, Inc. 152
L. W. Ramsey Advertising Agency

Rodney Metals, Inc. 174
Horton, Church & Goff, Inc.

Rohm & Haas Co, Plastics Div. 35
Arndt, Preston, Chapin, Lamb & Keen, Inc.

Russell, Burdsall & Ward Bolt and Nut Co. 174
Marsteller, Rickard, Gebhardt and Reed, Inc.

St. Joseph Lead Co. 183
Emil Mark & Co., Inc.

***St. Regis Paper Co., Industrial Panelyte Div.** 94
Cunningham & Walsh, Inc.

***Sandusky Foundry & Machine Co.** 54
Howard Swink Advertising Agency, Inc.

Scott Testers, Inc. 165
Horton, Church & Goff, Inc.

***Sel-Rex Corp.** 178
Bass and Co., Inc.

Shell Chemical Co., Div. of Shell Oil Co. ... 55
Ogilvy, Benson & Mather Inc.

***Simoniz Industrial Products, Div. of Simoniz Co.** 36
Russell T. Gray, Inc.

***Spaulding Fibre Co., Inc.** 84
Barber & Drullard, Inc.

Spencer Chemical Co. 93
Bruce B. Brewer & Co.

***Stackpole Carbon Co.** 156
Harry P. Bridge Co.

Stokes, F. J., Corp. 91
Aitkin-Kynett Co., Inc.

***Sylvania Electric Products Inc., Parts Div.** 29
Kudner Agency, Inc.

***Synthane Corp.** 190
Arndt, Preston, Chapin, Lamb & Keen, Inc.

Taber Instrument Corp. 188
Harold Warner Co.

Tempil Corp. 96
RAF Advertising Inc.

Timken Roller Bearing Co., Steel & Tube Div. .....Back Cover
Batten, Barton, Durstine & Osborn, Inc.

Titan Metal Manufacturing Co., Div. of Cerro Corp. 85
Sykes Advertising, Inc.

United States Testing Co., Inc. 176
W. L. Towne Co., Inc.

Vanadium-Alloys Steel Co. 171
Downing Industrial Advertising, Inc.

***Wah Chang Corp.** 25
Kelly, Nason, Inc.

Washington Steel Corp. 189
Cabbot & Coffman, Inc.

Weirton Steel Co., Div. of National Steel Corp. 164
Campbell-Ewald Co.

Welded Steel Tube Institute, Inc. 191
Griswold-Eshleman Co.

Wheeling Corrugating Co. 50, 51
Cunningham & Walsh Inc.

Wilson Mechanical Instrument Div., American Chain & Cable Co., Inc. 166
Reincke, Meyer & Finn, Inc.

***Wolverine Tube Div., Calumet & Hecla, Inc.** 99, 100
Gray & Kilgore, Inc.

***Zirconium Metals Corp of America, Div. of National Lead Co.** 18
Comstock & Co.

**These manufacturers advertised their products in the 1960-61*

MATERIALS SELECTOR REFERENCE DATA ISSUE

For more complete information, and application data on their lines, refer to the index of Advertisers in the Mid-November MATERIALS SELECTOR ISSUE of MATERIALS IN DESIGN ENGINEERING.

THE LAST WORD

by H. R. Clauser
Editor

The Testing Lag

■ "It is known that the uniformity, correctness and correct employment of measures and measuring devices is a matter of great importance for the national economy, since the use of incorrect measures and measuring devices causes unproductive losses, leads to an increase in production rejects, and to an incorrect assessment of material values." This is a quote from N. S. Khrushchev's address to the 21st Congress of the Communist Party of the Soviet Union.

For once, most of us will agree with Mr. Khrushchev. Our ability and competence in testing and measuring the properties and performance of materials *is* of critical importance to the technological and industrial progress of a nation whether it be Russia or the United States.

Taking Stock

Let's assess, then, the status of our testing activities as they relate to engineering materials. Are testing developments keeping pace with the developments of new materials? Are the tests adequate to predict how materials will perform in new and increasingly stringent environments? Are the measurements accurate and reliable enough to provide the design data needed?

Unfortunately, the answer to all of these questions is emphatically no. As the special report, "New Directions in Materials Testing," (p 117) clearly shows, our tests are seriously inadequate to meet our materials application and research needs.

It is true that a sizeable share of this testing lag is due to the formidable problems faced. But perhaps a more important cause of the lag is our failure to realize the fundamental importance of testing.

Not Enough Attention

This lack of appreciation of testing's vital role, has led us to pay too little attention to it. Too often we try to make do with existing tests that are not at all suitable for new materials. Too often we have been tardy in adopting new developments in electronic technology. Too often we have remained oriented towards "destructive" tests instead of investigating the as yet unrealized potentialities of nondestructive testing. And too often we have failed to make use of the new mathematical tools for designing our test programs and for making our results more meaningful.

But perhaps most important of all is our failure to develop a unified approach. There exists a kind of anarchy in the testing field today. For the most part each testing problem is tackled independently. C. J. Wessel in his article (*p 125*) says: "testing for effects of environmental deterioration on materials has been scattered, unorganized and unrelated . . . each investigation has proceeded without thought of its relation to similar investigations by others on related materials or problems." Similar comments could be made about all other property areas.

What to Do

What then can we do about this testing lag? First, we should raise testing to a level of higher importance in our engineering scheme of things. Second, we should make sure that our present empirical tests take full advantage of the advances being made in the sciences, in engineering, and in mathematics. And third, as suggested by several authors in the special report, we must increase our efforts to find ways to obtain materials behavior data at the microscopic levels from which we can accurately extrapolate engineering properties.

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